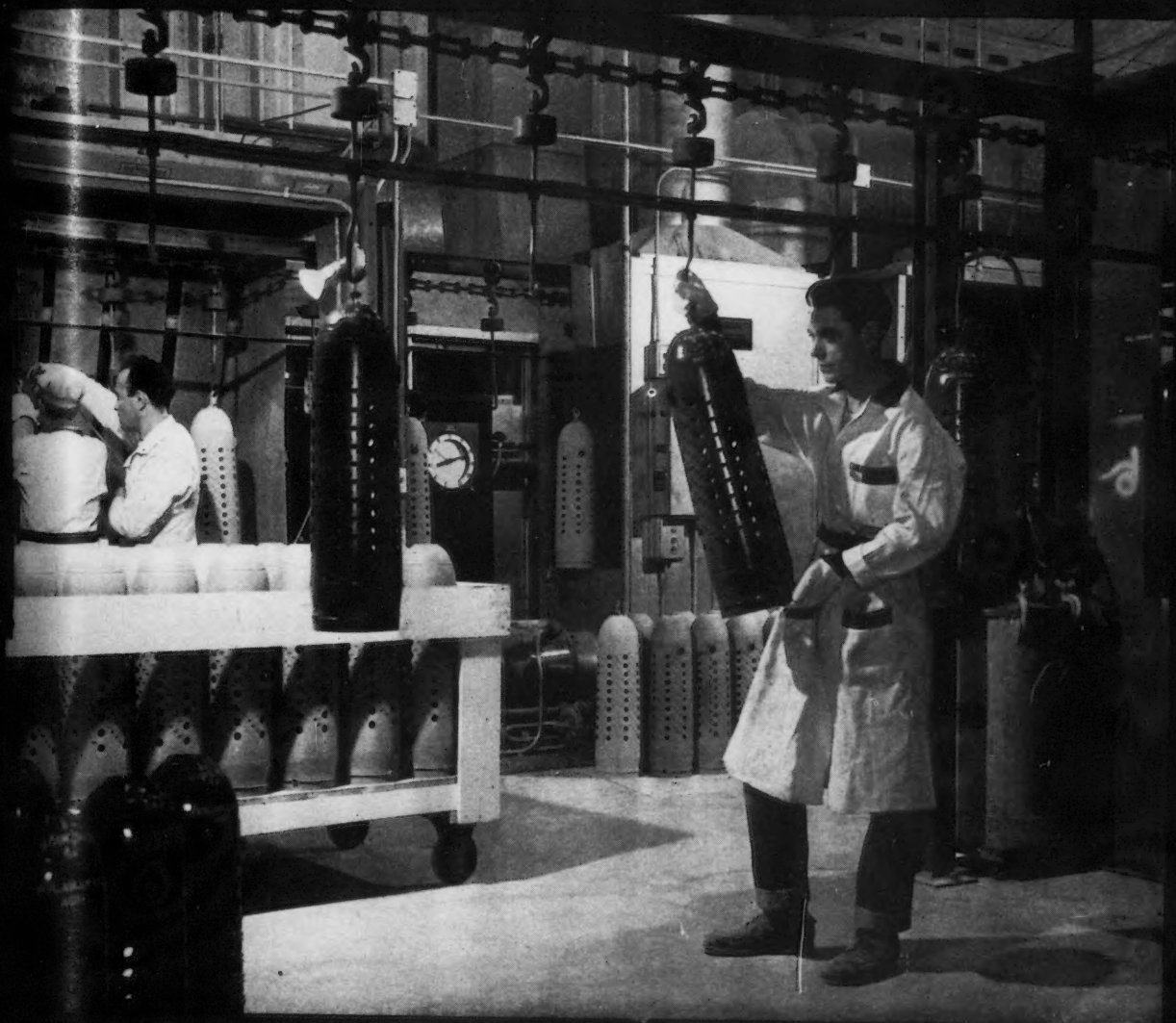



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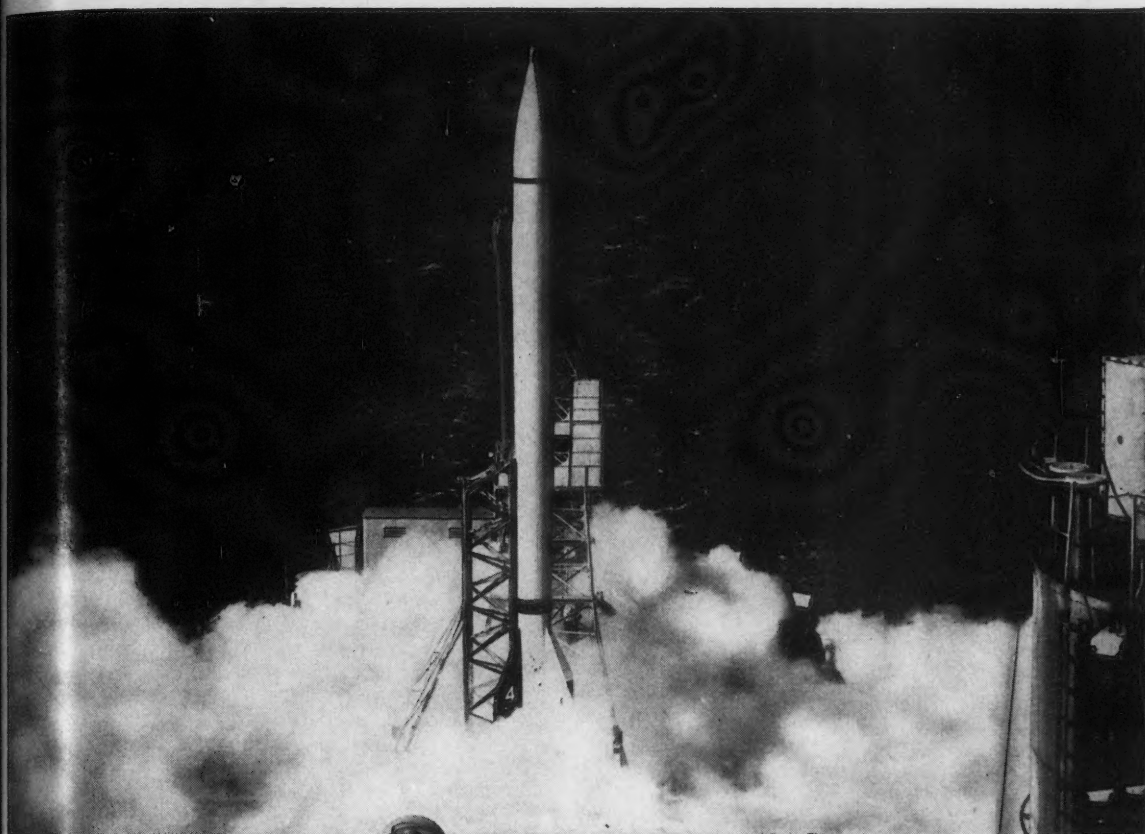
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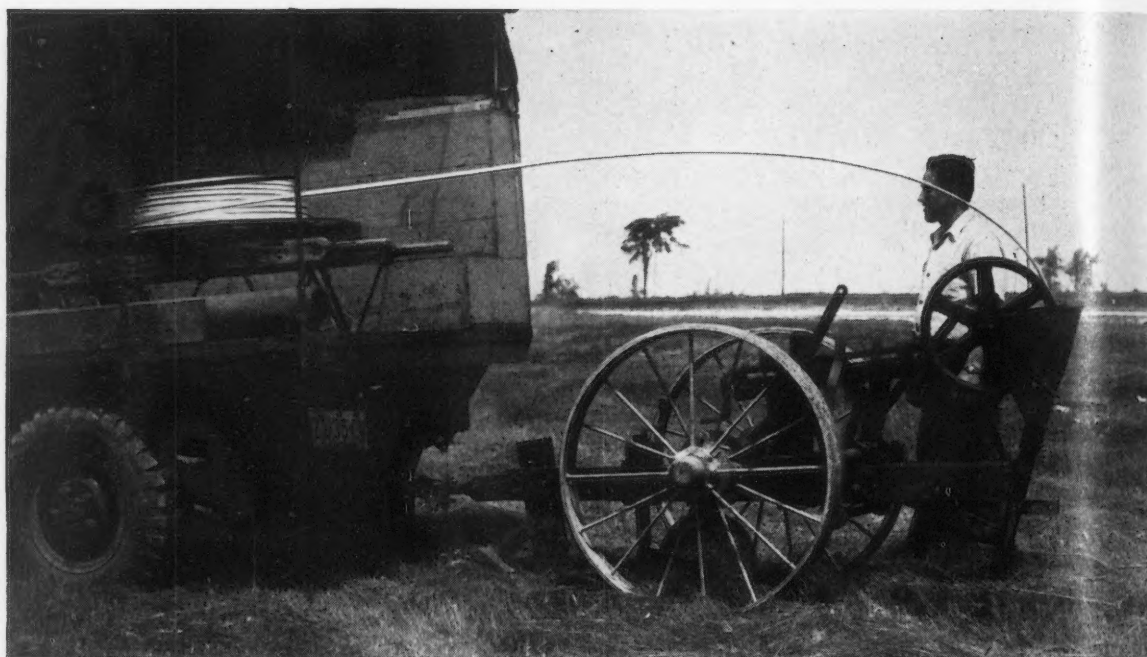
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THIS MONTH'S COVER—These combustion chambers for General Electric J47 turbojet engines are being processed with ceramic coatings to protect them against the corrosive effects of high temperature exhaust gases. The chamber shown is in the San Diego, Cal. plant of Solar Aircraft Company, and is said to be the first mass production facility of its type for applying ceramic coatings to alloy steel.



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(Continued on Page vi)

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Symposium On SULFIDE STRESS CORROSION

*Reprinted from Corrosion,
October, 1952.*

Consists of five papers, plus discussions presented at the NACE Eighth Annual Conference at Galveston, Texas, March 1952. 36 pages. Includes NACE Technical Practices Committee Report by TP-1G titled "Field Experience With Cracking of High Strength Steels in Sour Gas and Oil Wells."

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**NATIONAL
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1061 M & M Bldg. Houston, Texas



News about COATINGS for METALS

Metallic Organic Decorative Protective

How to benefit most from modern coatings

HOW SPECIAL VINYL COATINGS PROLONGED PUMP LIFE

Centrifugal pumps moving salt water for a processing plant were being replaced every 12 to 18 months because of erosion and corrosion of impeller and housing. Then impellers were coated with 30 mils of a vinyl Unichrome Plastisol Compound, the housings with 5 mils of an unusual vinyl Ucilon Coating System. After one year, inspection showed the coatings and pumps still in excellent condition.

This case illustrates the heavy duty protection given to metals by extra tough, resilient Unichrome Plastisols and Ucilon Protective Coatings. Applied by dipping or spraying, Unichrome Plastisols provide films from .003" to 3/16" thick. Do you have use for such a coating? Write us the details.

Vinyl drum lining resists many chemicals

There's no such thing as a "universal" drum lining — one usable with all types of chemicals. But there is, however, a Unichrome vinyl-type coating that withstands an unusually large group of them.

That's why Unichrome B-154 Lining was recommended to a chemical processor who was producing a variety of compounds and searching for a single lining to resist all. This coating was found to fill the bill — having withstood a full year of testing in contact with organic sequestering agents, sulfonated oils and textile finishing agents.

For drum lining data, send for Bulletin DL-1.



UNITED CHROMIUM, INCORPORATED
100 East 42nd Street, New York 17, N. Y.
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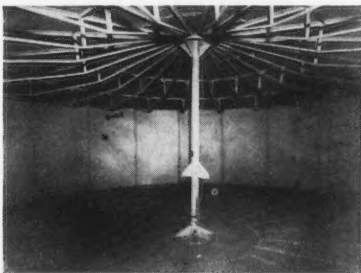
Unusual service life assured when Ucilon* Protective Coating Systems are specified as original-equipment-finish to meet corrosive conditions . . . and for maintenance, too.

Equipment designed for industrial use often encounters conditions so corrosive that ordinary finishes give short lived protection. What then? The maintenance engineer has to discover, often at considerable effort, protective coatings that can resist the strong corrosives; and then apply these to the surfaces which, at considerable extra expense, have again had to be adequately prepared for the refinishing.

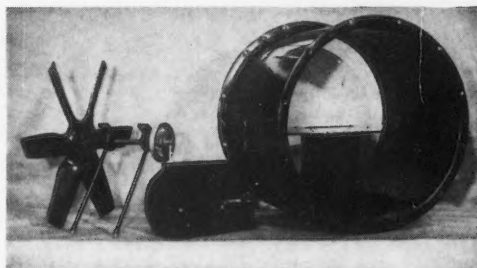
Systems of Ucilon Protective Coatings are being selected by many chemical, corrosion and research engineers for this job on the basis of their proved durability; also their resistance to strong acids, alkalis, salt solutions, alcohols, oils or other finish-destroying compounds.

PROTECTION SHOULD START WITH ORIGINAL FINISH

It stands to reason that if a coating system proves its worth when used for maintenance, it will prove even more worthwhile when used as the original finish. Thus, because of the unusually long protection obtained when Ucilon Coatings are applied to maintain equipment against corrosion-damage, more and more companies are now beginning to specify these coatings right from the start for new equipment. This not only improves the product functionally, but also simplifies subsequent maintenance.



Interior of large brine tank for which Ucilon Protective Coating System was specified.



New equipment to be in contact with corrosive fumes is better equipped for service with Ucilon Coating protection.

PROTECT AGAINST FUMES, CHEMICALS OR WATER

A great majority of coating problems arise from such conditions as continuous or intermittent contact with fumes, chemical solutions or water. Systems of Ucilon Coatings developed to combat these primary causes of coating failure include vinyl, phenolic, chlorinated rubber and fish oil formulations. Sixteen systems of Ucilon Coatings now exist which afford the needed protection and durability against over a hundred corrosives. A "system" may include special primers and intercoats in addition to a specific number of topcoats.

QUICK PICTURE OF RESULTS

Interior of brine tanks still protected 5 years after application of Ucilon Coating System . . . 5 years' service obtained against HCL fumes with virtually no patchwork of the Ucilon Coatings needed . . . No failure observed after almost two years of Ucilon Coating protecting tank car carrying saturated ammonium nitrate solution . . . Even after 3 years, no deterioration seen in Ucilon Coatings on steel submerged in sewage.

CONCLUSIONS

To get the most benefit from today's protective coatings, (1) determine what corrosives must be combatted; (2) select a Ucilon Coating System recommended for the conditions; (3) specify it for any new equipment to be installed; (4) apply it on present equipment and structural surfaces for longer lasting protection and to reduce frequency of "painting." Write for bulletin MC-7.

*Trade Mark

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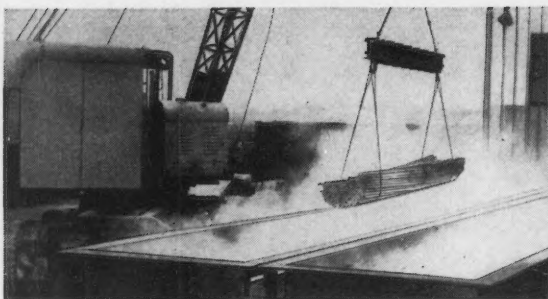
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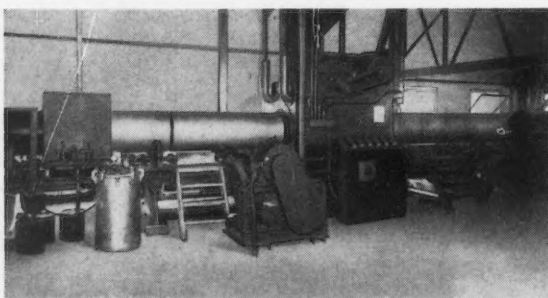


PROTECTIVE COATINGS CORP., 9 S. Fairview Ave., Park Ridge, Ill.
Please send us 12 oz. test sample of Kerpro V. P. I.

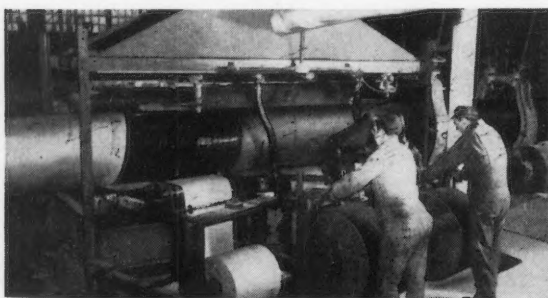
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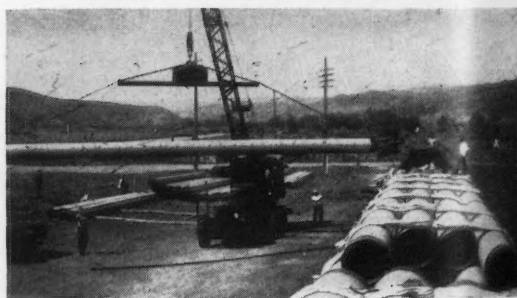
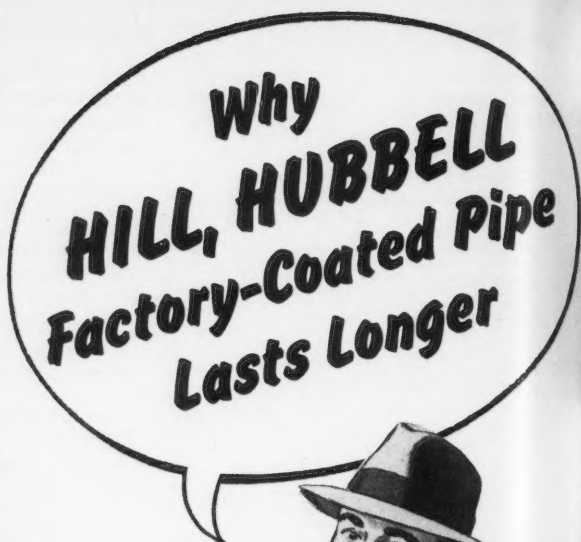
HOT CAUSTIC DIP removes all cutting oil and grease. Pipe is then rinsed in clear, hot water and dried in warming room. Throughout Hill, Hubbell process, pipe is kept at 80-90° to prevent moisture condensation.



ROTO GRIT BLAST removes all mill scale and rust, cleans pipe to bare, bright metal, provides a slight "tooth" to hold coatings in positive bond. Priming coat is applied immediately after Roto Grit Blast.



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ELECTRONIC holiday detectors inspect every length of pipe before it leaves a Hill, Hubbell plant—further insurance that coatings have dielectric strength to resist electrochemical corrosion underground.

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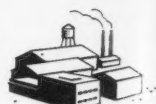


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**Pioneer in
Pipe Protection
for a
Quarter Century**



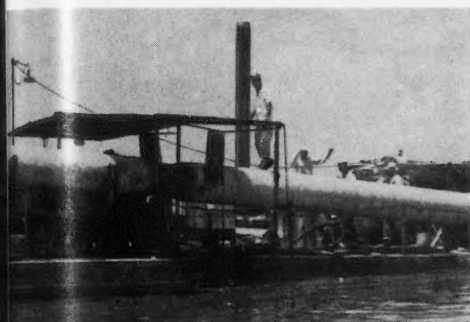
TYPICAL PACKAGED *INSTALLATIONS BY CPS SERVICE DIVISION

*(SURVEYED, DESIGNED, INSTALLED AND CHECKED OUT)



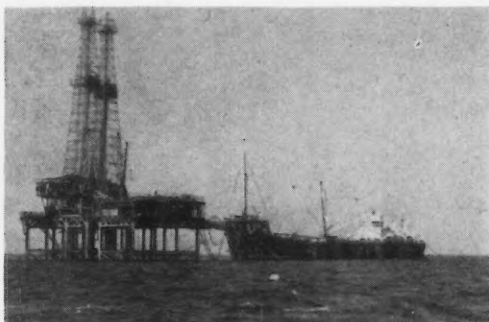
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City owned gas distribution system consisting of approximately 250 miles of mains and services (essentially bare) placed under complete protection with distributed magnesium anode system.



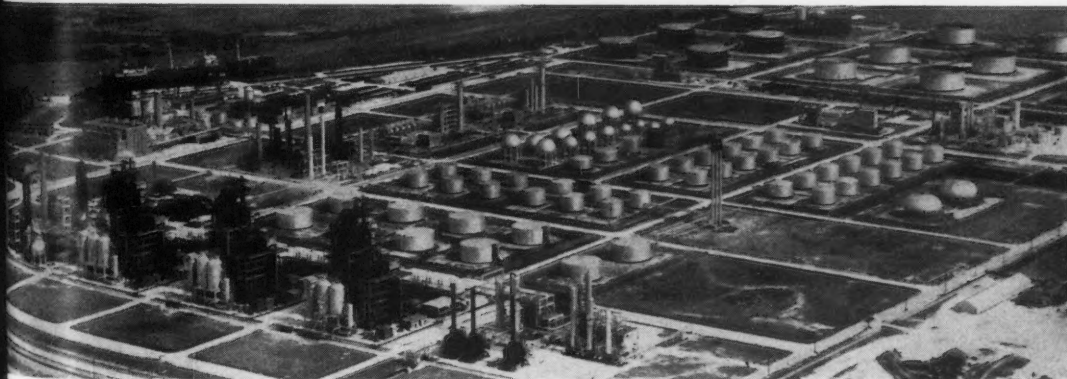
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Approximately 450 miles of 12" thru 24" consisting of the South Louisiana Project—approximately 150 miles of which was laid in marshy country and off shore with concrete casing—protected by a combination of magnesium anodes and rectifier/graphite anodes.



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The above is typical of some 45 offshore drilling rigs which have been placed under protection by CPS Service Division. Installations were combination of the high current density electro-coating technique and magnesium anodes.



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This advertisement is an exact reproduction of a page from our new catalog—CPS No. 54



CORROSION'S PLAYGROUND

Where **INSUL-MASTIC** stands guard!

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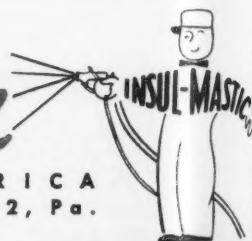
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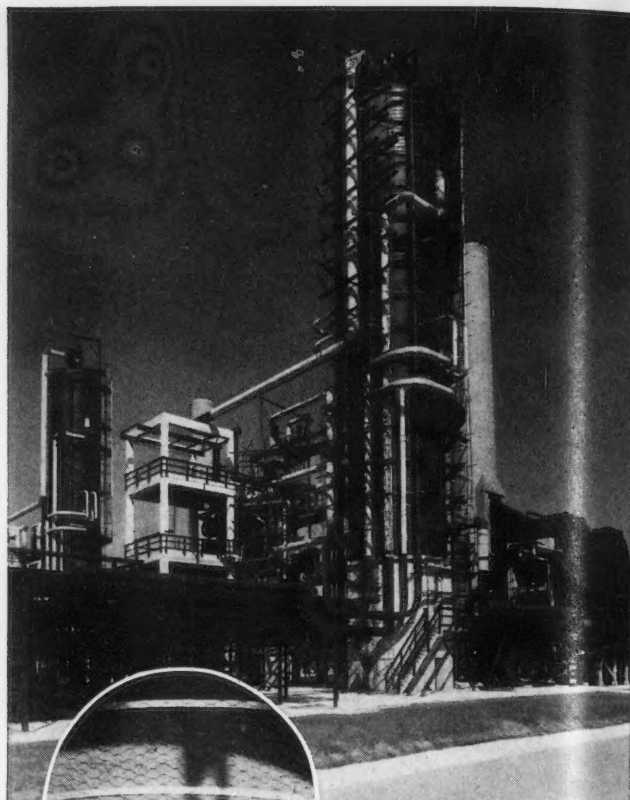
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- (a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.
- (b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.
- (c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.
- (d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.
- (e) To promote standardization of terminology, techniques, equipment and design in corrosion control.
- (f) To contribute to industrial and public safety by promoting the prevention of corrosion as a cause of accidents.
- (g) To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.
- (h) To invite a wide diversity of membership, thereby insuring reciprocal benefits between industries and governmental groups as well as between individuals and corporations.

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Organization and Functions of

TP-15 on Corrosion Control in the Transportation Industry

By Kenneth K. Kessler*

TECHNICAL Practices Committee 15 was organized with the intent that this committee should ultimately concern itself with corrosion problems in all fields of transportation, including automobiles, trucks, buses, railroads and aircraft, but excluding pipe lines and marine transportation. It was decided at the start to organize the committee to deal with corrosion problems of the railroad field only and to so plan this group that it could become a sub-committee at a later date and also to serve as a guide in the formation of similar sub-committees concerned with corrosion problems in other fields of transportation.

Thus far, the committee has concerned itself only with corrosion problems in the railroad industries. The present objectives, which will later be the objectives of the sub-committee on railroads, are as follows:

- To stimulate and encourage research and interest in determining the causes and methods of controlling corrosion in the railroad industry.
- To facilitate the exchange of knowledge and ideas among personnel actively concerned with problems relating to corrosion control in railroad industry and railroad supply field.

- To provide a means of circulating to interested parties in the railroad industry new and improved techniques and methods of corrosion control.
- To promote standardization of terminology, methods, equipment, etc., where desirable.
- To serve as a source of information on corrosion work being conducted in the transportation field.

Due to the magnitude of the problems confronting TP-15 it has been necessary to hold a minimum of three meetings a year and also form three sub-committees as follows:

- TP-15A—Corrosion Control of Railroad Tank Cars
 - TP-15B*—Railroad Suppliers of Corrosion Resistant Materials
 - TP-15C—Corrosion Control in Railroad Hopper Cars
- (*TP-15B is inactive for the time being.)

As a part of its program, Committee TP-15 issued a Corrosion Newsletter in January of 1952, which was distributed to the major American railroads. It was well received and a second issue is now being prepared. The Newsletter presents papers on various phases of corrosion prevention and serves as a medium whereby results of current investigations may be reported.

*Chairman, TP-15, Engineer Physical Tests, Research Dept., Baltimore & Ohio Railroad Co., Baltimore.

Members of Committee TP-15 as of September 1st are the following:

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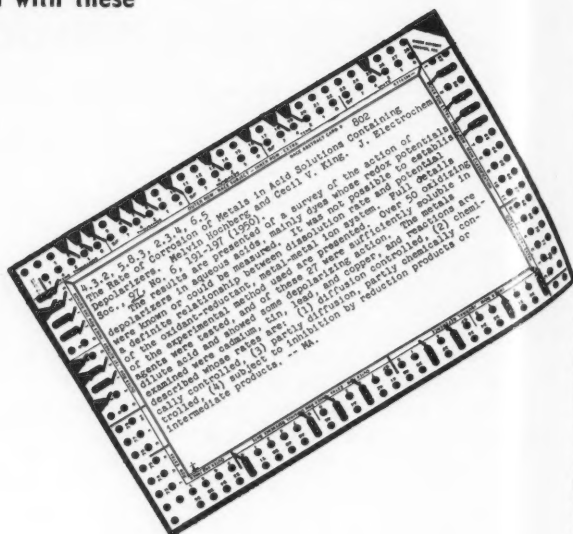
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HOUSTON 2, TEXAS

Symposium on Control of Internal Corrosion Of Tankers★

Part 1. The Nature of Corrosion and Its Control
By William B. Jupp⁽¹⁾

Part 2. Inhibitors in Cargo
By J. V. C. Malcolmson⁽²⁾, W. S. Quimby⁽³⁾,
Gwendolyn D. Pingrey⁽³⁾, and J. C. D. Oosterhout⁽⁴⁾

Part 3. Corrosion Control in Practice
By A. B. Kurz⁽⁵⁾

★ Reprinted from *Transactions of the Society of Naval Architects and Marine Engineers*, Vol. 60, 382-441 (1952).

- (1) Manager, Construction and Repair Division, Marine Transportation Department, Socony-Vacuum Oil Company, New York.
- (2) The Texas Company, Assistant General Manager, Marine Department, New York.
- (3) The Texas Company, Refining Department, New York.
- (4) The Texas Company, Refining Department, Port Arthur, Texas.
- (5) Vice-President, Keystone Shipping Company, Philadelphia, Pa.

(EDITOR'S NOTE: Figures 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 21, 22, 23, 24, 26, 27, 28, 29, 31, 32 and 34, which appear in the original publication of this symposium were not available for use in this reprinted version.)

Part 1. The Nature of Corrosion and Its Control

By WILLIAM B. JUPP

Topical Outline

- Tanker Corrosion
- Corrosion Rates
- Methods of Corrosion Control
- Types of Corrosion Control
- Available References

Tanker Corrosion

THE CORROSION in the cargo spaces of tankers shows a wide variation, dependent upon the trade route, the type of cargo carried and the frequency of ballasting and cleaning tanks. Vessels operating exclusively in fresh water show a low rate of corrosion regardless of the type of cargo. Some river barges and tankers on the Great Lakes, with which I am familiar, have required no repairs to the cargo spaces after 14 years in service, regardless of predominately clean trade during this period. On the other hand, vessels operating in salt water have developed serious bulkhead failures in six to eight years of clean trade when frequent cleaning has been required.

A study of tankers operating in the ocean and coastwise trade should furnish the best data on the cost rate and nature of corrosion, as well as points of the greatest wastage. The data and comments herein are based primarily on the analysis of corrosion gathered from some twenty ships, some riveted, some welded, all operating in the Gulf-East coast trade alternating between clean and dirty cargoes. If a tanker is to make its anticipated 20-year life in the above trade half in the clean service and half in the dirty service, the data would indicate that it will be necessary to renew completely all internal structure in this period, with partial renewal of deck and bottom plating and also with some renewals of framing.

A recent estimate for the complete renewal of internal structure of cargo space indicated that this would cost a minimum of \$750,000. Work on the partial renewal of deck, shell and bottom plating, including some longitudinals, could not be covered for less than \$250,000. In round figures the expenditure for steel work to maintain a 20-year life (one half in dirty and one half in clean trade) would be in the neighborhood of \$1,000,000 for 500 cargoes between Gulf/North of Hatteras. I will assume for the moment that corrosion is three times as rapid in the clean trade as in the dirty trade. It therefore follows that if the 500 cargoes are operated as 250 clean and 250 dirty, the corrosion cost of the clean cargoes is \$750,000, or \$3000 each, and the cost of the dirty cargoes is \$250,000, or \$1000 each. Looking at it another way, the 250 dirty cargoes at one-third the corrosion rate would be equal to one-third this number of clean cargoes, or 83 cargoes. These 83 equivalent clean cargoes added to the 250 clean cargoes would make

Abstract*

Part 1. The Nature of Corrosion and Its Control. Tanker vessels operated in salt water have developed serious bulkhead failures in 6 to 8 years of clean trade when frequent cleaning is required. Estimating tanker service as one-half each in clean and dirty trade, the author says partial renewal of deck, shell and bottom plating, including some longitudinals, plus complete renewal of internal structure of cargo space would cost \$1,000,000 for 500 cargoes between Gulf/North of Hatteras. Figures are given on actual percentage and dollar damage resulting from tanker corrosion. Elements of tankers most subject to corrosion damage are enumerated and illustrated and design remedial measures discussed.

Methods of corrosion control are enumerated and some experience with the several methods considered. Means of protecting cargo space by treating cargo, cathodic protection, inhibition, dehumidification, deoxidation are reviewed. The advantages of adding extra metal to members subject to greatest corrosion losses are explained and dollar savings given.

(*Note: This abstract was not a part of the original publication of Part 1.)

an equivalent of 333 clean cargoes in the 20-year life of the ship. Most of this expenditure is, of course, in the second half of the ship's life. It can be expended on a year-to-year basis or in one or two major overhauls.

To place this figure in another light, in a fleet of 20 ships in this service, the cost would be \$1,000,000 per year or \$50,000 per year per ship, \$75,000 per

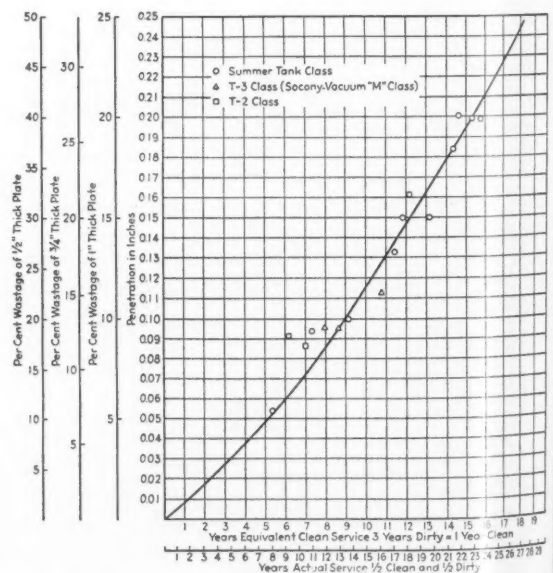


Figure 1—Tanker corrosion curve. Based on average corrosion of internal and external cargo tank surfaces August 1952.

year for the clean trade and \$25,000 per year for the dirty trade. This expenditure does not include the cost of cargo pipes, valves, reach rods, etc.

In the early thirties, the ships of the summer-tank type built during and immediately after World War I were carefully drilled to determine the necessary steel renewals to extend their life. These data were analyzed in an effort to determine the rate of corrosion. An effort to plot the amount of wastage against time or number of cargoes gave a very good plot when a time scale was adopted using time in the dirty service evaluated at a corrosion rate of one-third that of clean service. (See Figure 1).

It will be noted that at the end of nine years of service, where three years of dirty trade equals one year of clean trade, that the average corrosion was 0.10-inch or a rate of 0.011-inch per year on a clean trade basis. In the next six years, however, the corrosion had accelerated to an average of 0.015-inch per year, an increase of 35 percent in the rate of corrosion. The external or shell plating corrosion average is very close to that of the internal members, although they are exposed to the cargo on one side only. This is due to the very high rate of wastage under deck. When the deck wastage is averaged with the shell wastage the result as stated above is very close to average wastage of the internal members.

The general wastage is shown in percent of the original thickness for various thicknesses of plate, as well as actual loss, as renewals usually are required when the general wastage exceeds 25 percent of required scantlings, particularly in the shell. Rebuilding becomes absolutely essential in any part of the structure before it reaches 40 percent because of the much higher rate of wastage when the material is so far below the designed scantlings.

The wastage data on ships built after the mid-thirties also have been plotted on this same curve. They show the same rate of corrosion as the older ships when plotted on this scale. Their higher speed, however, represents 25 percent more cargoes carried in the same period. These new ships have had some treatment of inhibitors after tank cleaning which may be a factor in the increase in cargoes carried.

Several of the new ships had about 0.04-inch extra thickness added to the upper structure and therefore the percentage loss below the required scantlings in this case must be replotted when consideration is given to renewals. The increased scantlings in plates under one-half inch in thickness required about 60 to 80 tons of metal. It has given an increase in life of about four years before requiring replacement.

In Figure 2 the wastage data used to determine the general corrosion rate were analyzed again to determine the relative loss of metal in the various parts of the structure. A number of modern tankers were used for this purpose. The data correspond closely to that of a previous study of the old summer tank ships. The average wastage of the shell is not far different from the bulkheads although only one side is exposed to the cargo. The greatest wastage is in the deck plating and framing—even greater than the bulkheads.

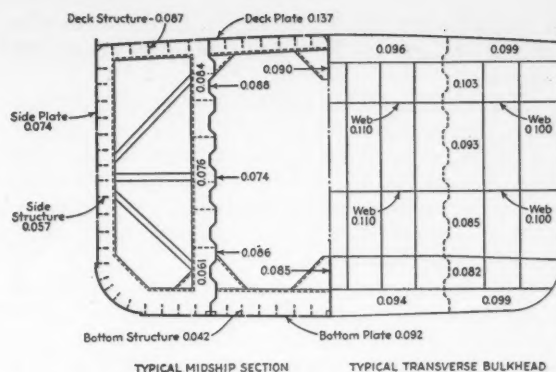


Figure 2—Average penetration in inches for eight years of clean service. Note: Above average penetration in inches is the average of seven T3 and T2 tankers. Penetration is the average for both sides.

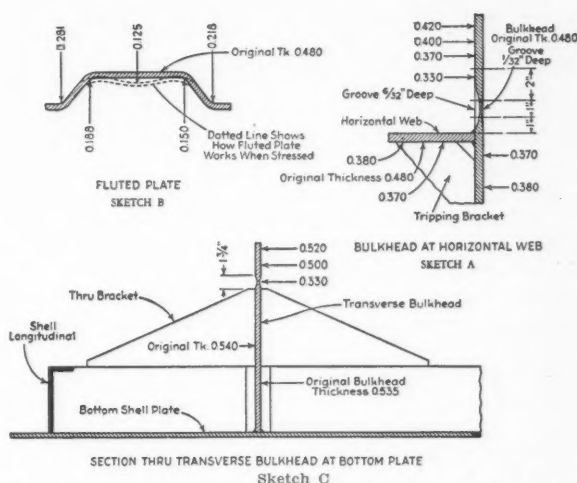


Figure 3—Local corrosion. Note: Sketches A, B and C are for vessels with eight years' equivalent clean service.

The bulkheads and their framing show a difference in corrosion rate of only about 10 percent more in the upper spaces than at the bottom. This is roughly in inverse proportion to the thickness of the plates and also is true of the general corrosion curve indicating that fatigue corrosion may be a factor. When these wastages are put on a percentage basis, the picture changes, showing a much higher percentage in the lighter upper cargo structure and deck plates and frames. It also is of interest to note that the corrosion is greater where the steel is exposed to moisture and sweating from change of temperature by heating in the sun, cooling at night, etc.

It was impossible to find excessive corrosion in the tanks normally used for ballast. If corrosion due to sweating is a predominating factor, as indicated by these figures, one would anticipate the greater corrosion on the empty side of a ballasted tank where both moisture and oxygen are present. It is well known that both are required in normal corrosion and the rate of corrosion is much greater with a high oxygen content than when the amount of oxygen is restricted as in a ballasted tank. It has been pointed out very clearly that there is need of maintaining a pH value

of the moisture film in contact with the steel of at least 10 to lower the corrosion rate in the presence of oxygen.

Data from two ships operating on the West Coast, where less cleaning and gas freeing are required with a consequent lowering of the moisture in the tank, show a decidedly lower rate of corrosion. No difference was found in the corrosion rate of ballasted tanks as compared with the tanks normally empty on the ballast run.

The local corrosion shown in Figure 3 unfortunately is not of equal intensity throughout each of the various panels between stiffeners making up the bulkheads, but is as much as three times as rapid at the points of maximum working or hard points in the general structure. These points cause failures in cargo segregation long before the general corrosion gives difficulty.

The maximum local corrosion occurs at hard points or the points of maximum flexure or strain; that is, at the points of working of the structure or the points of high cyclic stress not necessarily at the parts of the structure under the heaviest load or stress. In other words, a distinction must be drawn between uniformly distributed stresses and local hard points where cyclic stress or fatigue play an important part.

Sketch A of Figure 3 shows the grooving of the bulkhead plate above a web or horizontal stiffener. This local corrosion is particularly aggravated at the limber hole in the horizontal web. The web itself is grooved in the same manner. These grooves may run toward a lightening hole. This condition is not found on the bulkhead under a web stiffener. The usual shallow pits, however, are present as in other parts of the structure.

Sketch B is interesting as it shows the same effect on a fluted bulkhead where the shape of the sides of the flute allow this flexuring to take place in the middle of the panel. Here a section in the middle of the panel is reduced to about one-half that at the knuckle of the flute. This type of corrosion requires expensive patching before the structure as a whole has failed to a point requiring renewal.

Sketch C shows the same situation at the bracket through bulkheads for shell longitudinals. This condition does not occur at brackets adjacent to a cargo pipe through the bulkhead which helps stiffen the plate at the nearby brackets and thereby restricts the working of the plate.

Cyclic stresses or fatigue alone may account for these very rapid failures. In each case the scale was broken (presumably due to flexure or working of the plate). The condition in each case was more marked on an upper surface of a horizontal stiffener than on

the underside, or on a vertical stiffener. This holds true on brackets with their points up rather than on deck longitudinal brackets with their points down. At first this appeared to be due to an accumulation of loose scale and the consequent moisture. Recently, in scaling a section of a bulkhead, it was noted that a considerable amount of moisture drained from the scale immediately above. This moisture could contain concentrated brine or other material to make it a strong electrolyte. If this is so, it would help explain these local failures.

Pitting plays its part in corrosion. The pits do not tend to progress on the vertical surfaces, as the scale breaks free before deep penetration occurs. This is not equally true on the bottom plating where this condition can become very troublesome, particularly when carrying sour crudes. As sour crude pitting is not considered a major corrosion deterioration problem on the majority of tankers now in operation, pitting penetration was not considered in Figure 1, which indicates the overall average corrosion penetration plotted on an adjusted time basis.

It would be helpful to know when the corrosion is most active. Does gasoline alone cause corrosion? Is ballast the worst offender? There are considerable data indicating that moisture with a low pH value and high oxygen content will produce the most rapid corrosion unless the residual cargo protects the steel.

Table I summarizes these conditions.

The cargo, whether clean or dirty, is an excellent insulator and it inhibits corrosion where the tank is loaded with cargo. The heavier petroleum leaves a coating on the steel which gives protection in an empty tank. Gasoline, however, cleans the steel and exposes it to corrosion when moisture is present. Cleaning with sea water adds moisture and accelerates the rate of corrosion.

The above data, in conjunction with the well-known theories of corrosion, indicate that the assumptions reached appear to be logical. Here are indicated, I believe, some of the points where research and controlled tests aboard ship could help in giving precise answers to such questions as:

1. What percentage of the over-all corrosion occurs under the various conditions of cargo-ballast-clean, etc.?
2. What is the difference in corrosion between the plate not under strain or not working and that of one subject to high strains or flexing under load?
3. Does the rough surface of an already corroded plate increase its rate because of the increase in surface, or is the increasing rate of corrosion due to its greater unit stress?
4. Does the breaking away of scale at the points of flexure in itself affect the rate of corrosion?
5. What percentage of the corrosion occurs on the side of the plate carrying ballast and in the empty tank due to sweating from differences of temperature of the ballast and the empty tanks?
6. Would the removal of scale reduce or accelerate the general corrosion?
7. What effect would an occasional fresh water wash of the rusted bulkheads have on removing brine and how would this affect the corrosion rate?
8. What is the chemical analysis of the water retained in heavy scale under varying operating conditions?
9. What is the corrosion rate of steel in a hot salt saturated atmosphere, in comparison to a steam saturated atmosphere?

TABLE I—Corrosion Rates

Type of Cargo	CONDITION OF TANKS			
	Loaded	Ballast	Empty	Cleaned
White products.....	Minor	Moderate	Major	Maximum
Light fuels.....	Minimum	Minor	Moderate	Maximum
Crude and heavy fuels..	Minimum	Minor	Minor	Maximum
Sour crudes.....	Moderate	Major (bottom plate)	Major	Maximum

Methods of Corrosion Control

There have been many methods of approach to reduce this costly corrosion. To oversimplify these methods, I believe they can be classed in two types:

- A. Mechanical approach
- B. Electrochemical approach

Table II shows the two approaches with three subheads under mechanical:

1. Coatings
2. Designs
3. Materials

and four subheads under electrochemical:

1. Oxygen elimination
2. Moisture elimination
3. Chemical inhibitors
4. Impressed potential

These various methods are not all equally effective under the various conditions of cargo-ballast-empty-clean, etc. If the relative rates of corrosion mentioned earlier are accepted it is then desirable to use the methods best adapted to control corrosion when oxygen and moisture normally are present, that is, when the tanks are empty or clean. (Sour crudes, with their high sulfur, require special treatment to control hydrogen sulfide corrosion in the upper spaces and acid corrosion on the bottom plates.)

The three mechanical approaches are all effective regardless of the tank condition, provided they can be successfully applied.

Coatings have probably been experimented with more than all other methods. The results have not been encouraging. The most common failure has been lack of adhesion and inability to obtain a clean surface for application of the coating. The necessity of maintaining a firm coating under cargo ballast and hot salt spray when cleaning offers many problems. If the coating is porous or cracks, rust will form behind the coating and destroy its adhesion. Sample patches for test under careful control of application usually give better results than large-scale application. A recent test of a vinyl coating gave favorable results.

Coatings in the cargo spaces of vessels operating exclusively in fresh water have been satisfactory, particularly where all ballast is carried in double bottoms. A well-known tanker fleet operating in fresh water has successfully applied raw linseed oil for many years.

Sprayed metal has shown good adhesion provided the surface is properly prepared. Rust is inhibited behind the sprayed metal and it, therefore, tends to retain its adhesion. Metal spray can be classed also under the heading of "Impressed Potential" and will be dealt with later.

Carefully applied coatings during construction over the limited surfaces subject to high rates of corrosion fatigue should be helpful even if the coating is effective only for a limited time. The applications to these points before erection have time to harden and can be applied at less cost than later.

Design has made some progress, particularly in the reduction of some of the major hard points. The local hard points of maximum flexure or strain in

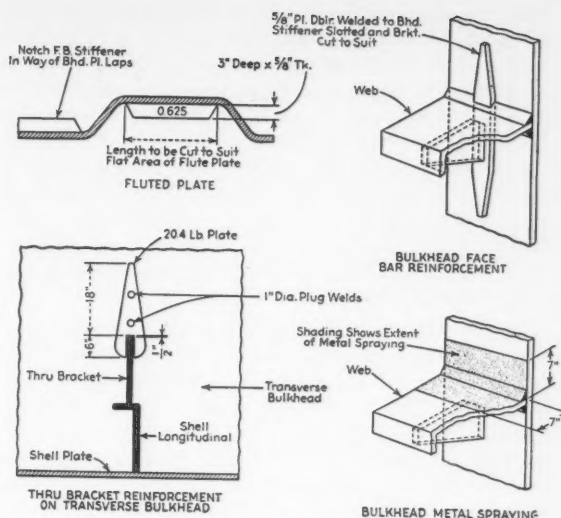


Figure 4—Repairs to local hard spots.

TABLE II—Types of Corrosion Control

Corrosion Control	EFFECTIVENESS OF VARIOUS METHODS OF CONTROL			
	Loaded	Ballast	Empty	Cleaned
Mechanical:				
Tank Coatings.....				
Structure design.....				
Structure material.....				
Electrochemical:				
Eliminate oxygen.....	No	No	Yes	Yes
Eliminate moisture.....	? Yes	No	Yes	Yes
Chemical inhibitors:				
In cargo.....	Yes	??	? Yes	? No
In ballast water.....	No	Yes	No	No
Sprayed inhibitors.....	No	No	Yes	Yes
Impressed potential:				
Metallic anodes.....	No	Yes	??	??
Metal spray.....	Yes	Yes	Yes	Yes

the bulkhead plating have caused very high corrosion rates and local cracks. These points are of primary importance and require correction if a normal life is required in the internal structure in the cargo spaces because:

1. This corrosion fatigue rate is two to three times that of normal corrosion and,
2. It results in cracks which may propagate and cause serious failures of the structure or at least interfere with the segregation of different cargoes in adjacent tanks.

A pamphlet issued by the American Bureau of Shipping several years ago suggested methods of modifying the design to reduce this difficulty.

Some methods for the correction of local hard points are shown in Figure 4. These are not in common use but are now under test and proving effective, at least in the early stages of the tests. The long "V" shaped doubler at the points of brackets prevents the concentrated flexure of the bulkhead and avoids the accelerated corrosion.

The flat bar stiffener in the flat panel of the fluted bulkhead acts as a tripping bracket to the sides of the flutes. It should stop the flexure of the panel and retard its accelerated corrosion and cracking.

The wastage on the upper side of the horizontal webs and stiffeners is difficult to control. The fact that it occurs on the upper side only indicates that a strong electrolyte is draining from the scale above and with the ability to pick up oxygen where the scale has been broken away, together with the cyclic stresses, leads to an early failure at this point. Long diamond doublers or brackets on the top of the web should help control this wastage. Limber holes in webs have produced early failures in the webs. Coatings of sprayed metal and vinyl are under test in an effort to reduce the local corrosion.

Design can also consider an increase in scantlings of those members which require the earliest renewals. The data shown in the midship section and typical bulkhead indicate that the addition of 50 to 100 tons of steel in the upper sections will increase the useful life of these members by as much as four years, or 25 percent before renewal becomes necessary. Recent corrosion data on several T-3 type tankers, where scantlings were increased by a total of 75 tons, resulted in an increase of several years in the life of the upper portions of the structure, sufficient to extend their life to that of the lower portion of the bulkhead. These tankers already exceed the total of 120 clean cargoes which was the average carried in the old fleet before major bulkhead repairs.

Some of the special steels have been under experiment. The nickel copper steels have been used to reduce corrosion in acid conditions and indicate some advantage to be gained in tanker design. I have been familiar with a small tanker operating partially in salt water and partially in fresh water, with a special steel middle body which shows 30 percent reduction in the corrosion after 14 years of service when compared to sister ships in the same trade built of mild steel. This middle body was built to the same scantlings as the sister ships.

A similar test is now in progress in a group of large barges. Three barges are built of mild steel. The fourth barge is built of special steel in which advantage was taken of its high tensile strength to reduce the scantlings by about 15 percent.

Referring again to Table II, the electrochemical approach to inhibiting corrosion has received much more consideration during the postwar period than before. The corrosion taking place in tanker operation is dependent mainly upon water and oxygen in contact with the steel. The water need be only an infinitesimal film which may be more active than actual submergence of the steel because of the easy access of oxygen. If this water film can be removed or given a pH value in excess of 10, the corrosion is greatly retarded. Acid corrosion also may be a factor when carrying sour crudes but appears rather minor in normal tanker operation. Strain or flexure at hard points in the steel accelerates the corrosion rate at those points.

Some of the methods for the electrochemical control of corrosion are effective under all the various operating conditions but others are not. This is shown in Table II. The elimination of oxygen usually is effective only in an empty tank. It could be made

effective in the vapor spaces in a loaded or ballasted tank. The elimination of moisture can, of course, be effective only in a tank free of ballast. Raising the pH value of the water or the moisture can be applied either to ballast water or the moisture in an empty tank or in a clean tank; each of these three approaches requires a different method of chemical treatment.

Impressed potential or galvanic protection can be made effective in a ballasted tank. In time this might plate a protective coating on the steel. This coating has not yet been proved effective for any length of time in protecting the steel from corrosion after the impressed potential is eliminated.

The use of sprayed metal anodic to the steel at the local hard points can be effective in protecting these points of maximum corrosion, whether in ballast or empty, both by preventing the moisture from reaching the steel and by reversing the potential if the moisture penetrates the sprayed metal; it also prevents the formation of pits which are stress raisers and thus cuts down the fatigue failures.

The inhibiting of corrosion is much more important when light products have been carried or the tanks cleaned because the residual film left by the heavier cargoes is generally accepted as an efficient corrosion barrier.

The first method, that of eliminating the oxygen, has been tried by the use of flue gas which also is used for inerting the explosive mixture in the tank. The process consists of washing the flue gas and passing it over calcium carbonate to remove sulfur products. This involves considerable equipment, including blowers to carry the gas through the vent or specially installed lines to carry the flue gas to the tanks.

The flue gas entering the tanks still contains some oxygen. It must be treated very carefully to accomplish a complete removal of corrosive sulfur products. This gas undoubtedly is of a high dew point because of the necessity of washing it. The tests which have been carried out have been primarily under the supervision of one company. I have no information as to its effectiveness in reducing corrosion in the cargo spaces so treated.

The second method, that of dehumidifying the air or gases entering the cargo spaces, is in operation in several American tankers and is being installed in a number of foreign flag tankers. It can be used under all cargo conditions except when in ballast or while Butterworthing. Several complete installations have been in operation for more than a year.

A dehumidified atmosphere above the cargo or in an empty tank prevents condensation. It also can dry out a tank wet from recent ballast or cleaning. Removal of moisture on the tank surface eliminates galvanic action and renders any electrolyte inert and unable to promote corrosion. This dry atmosphere is weather air reduced in dewpoint by a dehumidifier and is delivered through cargo lines, vent lines, or preferably a separate supply line with branches to the cargo tanks. As a forced ventilation system it is used for purging and gas freeing. The manufacturers anticipate that this treatment will eliminate the need

of rebuilding cargo tanks bulkheads through the normal life of the ship.

The third method, that of raising the alkalinity of the water or moisture divides itself into several parts:

1. In ballast
2. Empty and gassy tank
3. Empty and cleaned tank.

In each case the fundamental treatment introduces a chemical to raise the pH value to 10 or above. Laboratory tests indicate that a reduction of corrosion to one-half is well within the province of possibility.

In dealing with ballasted tanks, the nature of the ballast water is quite important and one treatment is required for clean sea water whereas different treatments are required for each of the different harbor waters. The quantity of chemical involved makes the process quite expensive. This treatment would not take care of the void spaces at the top of the tank except possibly by splashing.

The empty tank can be taken care of by inhibiting chemicals placed in the cargo (usually gasoline), which leaves sufficient residue of inhibitor on the tank structure to be effective after the cargo is pumped out. This is a very simple method of taking care of the empty tank. The use of this method in conjunction with a gas exhauster for cleaning, instead of washing with hot salt water, is anticipated to prove quite successful. Santoline "C" inhibitor is under test at present in several ships. In the event that the tank is washed, this residue inhibitor might be removed with the washing and would require replacing.

The method of spraying an inhibitor in an empty or a cleaned tank requires a mixture of chemicals and alkaline water in a tank. It also requires the use of a stripping pump to discharge through a strainer into the smothering line and thence into the tank by the Butterworth or spray system.

The first attempt to use this method was made shortly before the last war by the use of slaked lime and water. This caused considerable damage to the pumps. Since that time sodium bichromate and trisodium phosphate with a wetting agent to penetrate the scale have been used. The effectiveness of this method has been difficult to measure due to the difficulty of routine spraying because of short ballast runs in the present high-speed ships, bad weather, tank cleaning for change of cargo and week-end work with consequent overtime by the crew.

The results although inconclusive indicate a reduction in corrosion in spite of the fact that the treatment was carried out on an average of not more than every third or fourth voyage. The results with only sporadic treatment have indicated that the vessels could carry about 25 percent more clean cargoes before extensive repairs.

The method of impressed potential or galvanic protection divides itself into two parts:

- A. In ballast with possible carry-over protection to empty tanks.
- B. Local protection at the points of fatigue or high cyclic stress.

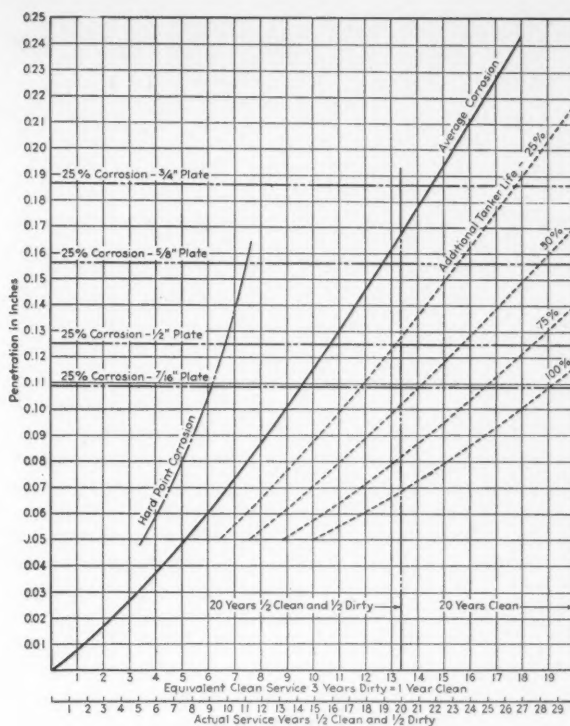


Figure 5—Extended life corrosion curves.

The first method has been used in some ships by placing anodes in the tank with the thought that the ballasted tanks would thus be protected. This should be effective when in ballast. The question arises as to whether this method is of value in an empty tank. Some research work would be required to see whether the resulting deposit built up on the steel during ballast is sufficient to inhibit corrosion in an empty tank.

Another method of using an anode is now being put under test on one or two ships. This involves spraying a less noble metal on the sand-blasted steel structure at the points of maximum corrosion or local hard spots. This should be effective in an empty moist tank as well as in a ballast tank. If this is successful it should reduce the rate of corrosion at this point where it is two to three times as heavy as in the rest of the structure. I refer here to the hard points similar to those shown in Figure 3.

A fresh water tank wash might remove the brine concentration from the scale. This, I believe, deserves study.

Figure 1 showed the rate of corrosion against service life and was compiled from analysis of more than 20 ships. Figure 5 shows this same basic curve. The newer ships plotted on this curve fell fairly close to it regardless of their increased speed and ability to carry 25 percent more cargoes in the same time. These ships had received some limited chemical treatment. Whether this ability to carry more cargo is due to chemical treatment or not cannot be ascertained until more information is available. It would indicate, however, that the time scale on the abscissa

might necessarily have to be modified for the higher speed of modern tankers to include a factor for the number of cargoes as well as the type of service.

The curve at the left shows the rate of corrosion for the hard points or points of stress fatigue which rate probably is accentuated by the drainage of the electrolyte from behind the scale. This electrolyte is undoubtedly a saturated solution of brine. If any life is to be anticipated from the structure in the cargo spaces this type of fatigue corrosion must be eliminated in the initial design or corrected as early as possible. The cost of these corrections, depending upon the design, has run, in my experience, between \$60,000 to \$100,000 per vessel. It is necessary to take care of this work before the corrosion has progressed to a point of seriously cracked bulkheads.

Over ten years ago the scantlings on some Socony "M" or "T-3" class and Maritime Commission tankers were increased in the upper parts of the cargo space. These vessels have shown the advantage of these increased scantlings by reducing the failures in this section so that the bulkheads are standing up in the upper portions equal to the structure in the middle and lower sections of the cargo space. This represents an estimated extension of life from 2½ to 4 years or a 25 percent increase depending upon the amount of metal added. The cost of this additional weight of metal has been about \$15,000 per vessel for an extension of four years in the life of the bulkheads. The first curve to the right in Figure 5 indicates what might be accomplished by this method in the upper tank structure.

The use of special anti-corrosive steel, as pointed out, showed an extension of life in excess of 25 percent. If the deck longitudinals and upper strakes in the cargo spaces were built of special steel, the cost per vessel for 1000 tons of steel at \$45 per ton additional would amount to \$45,000. The second curve to the right shows the extension of life that might be anticipated by this method.

The early data now available on the dehumidification, chemical treatment of the tanks and galvanic protection or a combination of some of these give every indication that we should be able to anticipate 25 percent to a 50 percent increase in life by the use of one or a combination of these methods. The right-hand curve shows what this might accomplish. You will note that the repair of hard points, using heavier scantlings, using anti-corrosive steel in part of the structure and the use of a treatment to inhibit corrosion, might possibly extend the life of the cargo spaces beyond twenty years, without major bulkhead renewals where the ship is operating half in the clean trade and half in the dirty trade. The cost of this is indicated as:

Correction of hard points including

metal spray	\$ 75,000
Increased scantlings	15,000
Anti-corrosive steel	45,000
Corrosion-inhibiting methods	65,000
Total	\$200,000

This cost is roughly \$10,000 per year on a 20-year basis as compared to this present cost of \$50,000. This indicates the possibility of saving \$40,000 per year per tanker with good corrosion control. The accomplishment of this objective is now in its preliminary stages.

If the present indications for estimated extension of the life of cargo spaces by the various approaches of improved design, better material, electrochemical control and correction of hard points, live up to the present test data, we can look forward shortly to controlling this vexing and costly problem.

First of all, hard points of high corrosion must be corrected early in the ship's life otherwise early bulkhead failure will occur.

Next the number of tank cleanings with salt water must be reduced to the minimum consistent with the required service of the vessel.

Finally, research must find the best and most economical approach under the various methods. Design details can be improved. Operators must carry out the proper treatment. These groups working together should in the near future be able to show marked progress in the control of corrosion in the cargo space of tankers.

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Part 2. Inhibitors in Cargo

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Topical Outline

History
Magnitude of Corrosion Losses
Methods Considered
 Paints
 Dehumidification
 Metallic Coatings
 Cathodic Protection
 Water-Soluble Inhibitors
 Oil-Soluble Inhibitors
Laboratory Evaluation of Method Chosen
 Modified ASTM Rusting Test (D 665-49 T)
 30-Day Static Storage Tests
 Cycling Procedure
Effect on Product Quality
Selection and Preparation of Vessel Used for Trial
The Actual Test
Results
Test Coupons
Costs
Conclusions
Tables

History

EVER SINCE man has gone down to the sea in iron ships, corrosion or rusting has been a major marine problem. With the advent of the tankship, carrying refined petroleum products, the problem became more serious. The increased cost of both steel and labor now has made the reduction or elimination of the rusting in clean oil cargo tanks an economic necessity and is one of the biggest problems facing this expanding industry today.

Dry cargo ships can be painted or otherwise protected against internal rusting. Oil tankers, particularly ocean going gasoline tankers, have an unusual series of circumstances which contribute to excessive accumulations of rust. The gasoline completely removes any oily film from the steel bulkheads. Upon discharge of cargo, the gasoline film on the interior surface evaporates and exposes clean steel. Also, upon discharge of cargo, salt water ballast is added to sufficient of these tanks to provide the proper degree of seaworthiness. This salt water readily attacks the clean steel, forming heavy rust. The salt atmosphere also attacks the steel not immersed in water and serious rusting occurs in both empty and slack tanks.

In ships carrying mixed cargo, such as gasoline, kerosene, Diesel fuel and furnace oil, it is necessary to clean the ships' tanks before another cleaner or higher quality cargo can be carried. This is generally done by washing with sea water while the ballasted ship is enroute back for another cargo. This sea water washing, commercially called Butterworthing or Pyrating, is done at 150-175 degrees F, using pres-

Abstract*

Part 2. Inhibitors in Cargo. Magnitude of corrosion losses in tankers is detailed. One typical tanker in coastwise service, after 195 mixed cargoes, or approximately eight years' service, had top 18 feet of all cargo bulkheads renewed at a direct cost of \$250,000, an average of \$1300 per voyage. Lower bulkheads must be replaced in four years, making total corrosion cost \$50,000 to \$75,000 a year for direct steel replacement costs. Additional costs include \$3000 to \$8000 a day for lost time while ship is under repair, the difference between normal drydocking and extensive bulkhead renewal being three to four weeks.

Tests on paints, dehumidification, metallic coatings, cathodic protection and water soluble inhibitors show these to be unsatisfactory. An oil soluble inhibitor, on the basis of a 9 months' comparative test, show Monsanto Chemical Company's Santoline C has sufficient merit to warrant additional investigation.

(*Note: This abstract was not a part of the original publication of Part 2.)

sure nozzles to wash off the residual petroleum products and to blast loose hanging scale. This loose scale constitutes a serious cleaning problem since it retains some of the previous cargo both in and behind it. The effect of sea water on clean steel is more severe than one might imagine, unless one is familiar with this service.

Rusting usually is rather generalized and uniform as contrasted to local pitting. Maximum rusting is believed by many to be experienced in the upper portions of the tanks. Bulkheads, underdeck surfaces and beams suffer most severely but the corrosion is acute throughout the entire inside of the tanks. Constant rusting over several years removes so much of the original metal that the ship eventually loses strength and no longer meets classification requirements. The most seriously affected members must then be replaced. The upper bulkheads and internal stiffeners are the first to require renewal.

Magnitude of the Corrosion Losses

The T2 type tankers of 16,600 deadweight tons, built by mass production methods during World War II, and carrying refined products, are suffering severely from this type of corrosion and after 8 to 10 years in clean oil service are rapidly coming to the stage when major internal steel renewals will have to be effected if they continue to transport clean oil products. The average coastwise clean oil tanker carrying mixed cargo is estimated as having from 6 to 10 years maximum operation before major repairs are necessary. The type of cargo carried, the number of cargoes carried, combined with the frequency of cleaning, all affect the over-all life of a tanker.

To illustrate the seriousness of this corrosion, a typical tanker carrying mixed cargoes engaged in coastwise service between the Gulf of Mexico and

the Atlantic seaboard will be described. This ship has a speed of 16 knots and completes about two round trips per month carrying clean oil cargo of 7 to 12 grades. This ship is in constant use except for routine inspections and dry-docking at 10- to 12-month intervals. After 195 such cargoes or approximately 8 years' service, it became necessary to renew completely the top 18 feet of all cargo tank bulkheads. The direct cost of this repair was in excess of \$250,000 and required more than 550,000 lb. of steel. This cost represents nearly \$1300 per voyage.

Although the above mentioned repairs have been made, the lower parts of the bulkheads (which are heavier originally) are also showing signs of wastage and will require replacements in approximately another four years if the ship remains in this service. The total cost of interior corrosion over the average life of a clean oil carrier is estimated by most experienced operators as from \$50,000 to \$75,000 per year for direct steel replacement costs, but this figure, under certain circumstances, can be much higher.

In addition to the direct repair costs, the additional loss of the use of the ship is also a major expense item, ranging from \$3000 to \$8000 per day, depending upon market conditions. This additional loss of time, coupled with costly repairs, as well as the desire to conserve man-power and vital defense materials makes the problem one which warrants close scrutiny and justifies considerable study in an endeavor to mitigate this heavy corrosion. The difference between normal drydocking and an extensive bulkhead renewal job may be in the neighborhood of 3 to 4 additional weeks.

Methods Considered

Many trials and tests of recommended methods of corrosion reduction have been conducted. These briefly can be described as follows:

Paints. Although laboratory and panel tests are attractive, full scale application of paints to the inside of cargo tanks has been unsuccessful mainly due to the extreme difficulty of thoroughly cleaning and preparing the surface for coating. Numerous estimates of the increased life expectancy of a tank with such paint coatings applied have indicated that they are not economically practicable.

Dehumidification. The practice of reducing the humidity of empty tanks to a point where corrosion does not occur has been tried and is successful. Its main objections are the amount of equipment necessary to handle the 26 or more tanks of, say, a T2 ship; the cost of operation and upkeep of the equipment; and the fact that this method is not effective when the tanks are in ballast.

Metallic Coatings. The use of sprayed metallic coatings, particularly zinc, was rejected due to the high cost of application and the difficulty of securing a sufficiently clean surface on which the coating can be properly applied.

In addition, zinc gradually oxidizes to white zinc oxide in contact with water and leaded gasolines, particularly aviation gasolines. This zinc oxide has

been found to contaminate the fuel carried and to interfere with engine operation unless carefully filtered out.

Cathodic Protection. The use of cathodic protection to lay down a resistant film of calcarious deposit on the steel to prevent subsequent rusting was considered. Although effective, it is limited by its ability to protect only tanks in ballast. Since common practice prevents the ballasting to the very top of the tanks, one of the most vulnerable surfaces is unprotected. The proposal to ballast each tank in rotation to lay down a protective film has not proved too practical from an operational standpoint. Often as many as 60 anodes, weighing 40 lb. apiece, are suspended in each tank. Each anode must be carefully positioned, suspended and maintained in good electrical contact with the hull of the vessel. A life expectancy of approximately 2 to 3 years is indicated before the anodes must be replaced.

Water-Soluble Inhibitors. The application of water soluble inhibitors to the entire quantity of ballast water has been considered but their cost has been more than the cost of the steel replacement.

Oil Soluble Inhibitors. Since the simplest means of depositing inhibitors appeared to be from solution in the cargo itself, this method was critically reviewed. Only by this method can costly and complicated apparatus be eliminated. A review of available compounds indicated that inhibitors of the oil soluble type were being used successfully in gasoline pipelines to combat internal corrosion. Although the conditions in a pipeline are acknowledged to be much less severe, the effectiveness of these inhibitors appeared to warrant further study.

Laboratory Evaluation of Method Chosen

Three methods were used in evaluating the merits of oil soluble inhibitors. These were the modified ASTM Rusting Test, a 30-day static storage test and

TABLE III—Effect of Inhibitors on Modified ASTM Rusting Test for Premium Grade Gasoline

Inhibitor	Dosage, Lb/M Bbl.	MODIFIED ASTM RUSTING TEST	
		Distilled Water	Synthetic Sea Water
None.....	0	3% covered, light rust	All covered, heavy rust
Inhibitor M.....	5	3% covered, light rust	All covered, heavy rust
Inhibitor M.....	10	3% covered, light rust	All covered, heavy rust
Inhibitor D.....	5	60% covered, light rust	85% covered, heavy rust
Inhibitor D.....	10	All covered, very light rust	80% covered, heavy rust
Inhibitor L.....	5	All covered, very light rust	All covered, light rust
Inhibitor L.....	10	All covered, very light rust	20% covered, very light rust
Santolene C.....	5	No change	No change
Santolene C.....	10	No change	No change
Competitive Gasoline No. 1.....	Unknown ¹	No change	80% covered, light rust
Competitive Gasoline No. 1.....	Unknown ¹	5% covered, very light rust
Competitive Gasoline No. 2.....	None	80% covered, heavy rust
Competitive Gasoline No. 2.....	None	100% covered, light rust

¹ Advertised as containing a rust inhibitor.

a cycling test. These tests are described briefly below:

Modified ASTM Rusting Test (D 665-49 T). Since gasolines are very volatile and the corrosion rate in their presence is high, it was expedient to reduce both the temperature of operation and the length of time of the D 665-49 T ASTM Rusting Test for steam turbine oils in order to use the test for gasolines. Briefly the method consisted of stirring 300 ml gasoline and 30 ml distilled water in the presence of a polished steel rod for three hours at 80 ± 4 degrees F. At the end of the three-hour period, the steel rod was removed and its appearance described. Table III shows typical data using this test.

30-Day Static Storage Tests. Since the modified ASTM Rusting Test, as described above, was run under conditions of considerable turbulence and since pipeline transportation is maintained under conditions of stream-line flow and tanker transportation under essentially quiescent conditions, it was believed desirable to supplement the Rusting Test with one having less agitation. Because of the number of samples involved and the storage period covered, it was believed expedient to make this test a static one.

Briefly the test consisted of placing a steel strip (5 inches x $\frac{1}{2}$ -inch 16 gage open hearth steel) into a tall 4-ounce bottle containing 15 ml water and enough gasoline to cover the strip (90-100 ml). The steel strip was placed slowly in the bottle, allowing gasoline to wet its surface before contact with water. The strips were examined visually at intervals and their appearances noted. It should be pointed out that whereas the test was essentially static, the strips were disturbed somewhat during the readings but no shaking or stirring was involved.

At the end of the 30-day storage period, the steel strip was removed from the 4-ounce bottles, scraped of all deposits, blisters, rust, etc., and the scrapings returned to the bottle. The gasoline phase was very carefully separated from the water by siphoning and the total iron oxide in the material remaining in the bottle was determined to serve as a quantitative measure of the attack on the metal. Table IV shows typical data using this test.

Cycling Procedure. The cycling procedure was a scheme to simulate the transportation service between Gulf and East Coast ports. This method consisted of storing for seven days in a tall 4-ounce bottle a weighed polished steel strip in contact with 5 ml synthetic sea water and 95 ml gasoline. The salt water and gasoline were then removed and 20 ml fresh salt water added and stored for an additional 7-day period. At the end of the second period the appearances of the strips were observed; the strips were removed, cleaned lightly with Dutch Cleanser, washed dried and weighed and the difference between the initial and final weights reported as a quantitative measure of the steel attack. Table V shows typical data using this test.

The foregoing tests indicated that Santolene C, a commercially available oil soluble, surface-active material, gave good protection against rust. It is supplied by Monsanto Chemical Company as a products

pipeline rust inhibitor and has been used by several pipelines with apparent success. It is reported to be similar in its action to a highly advertised gasoline inhibitor used by a major oil company.

Effect on Product Quality

Before the use of such an oil soluble inhibitor was recommended for full scale trial, information was needed regarding its effect on the quality of the product to which it is to be added. On the assumption that the dosage would not exceed 50 parts per million (12 lb. per 1000 barrels) complete tests were obtained on gasoline, kerosene, Diesel fuel and furnace oil, with this maximum content of rust inhibitor added. Table VI shows typical results on a sample of inhibited gasoline.

All of the results indicated that Santolene C had no detrimental effect on the product to be transported. Included in these tests were Coordinating Research Council High Temperature (L-4) and Low

TABLE IV—Effect of Inhibitors on 30-Day Static Storage Test for Premium Grade Gasoline and Synthetic Sea Water

Inhibitor	Dosage, Lb/M Bbl.	30-DAY STATIC STORAGE TEST	
		Distilled Water	Synthetic Sea Water
None.....	0	Few rust spots	50% covered, light rust
Inhibitor M.....	5	75% covered, med. rust	90% covered, light rust
Inhibitor M.....	10	60% covered, med. rust	All covered, light rust
		Several $\frac{1}{4}$ -in. blisters	
Inhibitor D.....	5	10% covered, med. rust	95% covered, med. rust
Inhibitor D.....	10	75% covered, black spots.	80% covered, light rust
		Balance not rusted	
Santolene C.....	5	Few pinpoints of rust	5% heavy rust, balance not rusted
Santolene C.....	10	Few pinpoints of rust	10% covered, very light rust
Competitive Gasoline No. 1.....	Unknown ¹	No change	75% covered, light rust

¹ Advertised as containing a rust inhibitor.

TABLE V—Effect of Inhibitors on Polished Steel Strips in Cycling Test for Premium Grade Gasoline

Inhibitor	Dosage, Lb/M Bbl.	Weight Loss of Strip, mg
None.....	0	46
Inhibitor M.....	5	76
Inhibitor M.....	10	68
Inhibitor D.....	5	54
Inhibitor D.....	10	68
Inhibitor L.....	5	24
Inhibitor L.....	10	20
Santolene C.....	5	15
Santolene C.....	10	9
Competitive Gasoline No. 1.....	Unknown ¹	18

¹ Advertised as containing rust inhibitor.

TABLE VI—Effect of Santolene C on Premium Grade Gasoline Tests

Dosage, Lb./M Bbl.	0	12.5
Tests:		
Gravity, °API.....	59.0	58.8
Color.....	Red	Red
Doctor Test.....	Negative	Negative
Sulfur, Lamp. Percent.....	0.050	0.051
Corrosion, Copper Strip at 122° F.....	Negative	Negative
Gum, ASTM, mg/100 ml.....	2	.2
Gum, Copper Dish, mg/100 ml.....	11	16
ASTM Induction Period, Minutes.....	480	515
Octane No. ASTM, Research.....	91.2	91.2
TEL, ml/gal.....	2.70	2.69
Distillation, ASTM		
1.B.P., °F.....	106	99
10% Evaporated.....	133	129
20% Evaporated.....	158	156
50% Evaporated.....	233	230
90% Evaporated.....	348	344
End Point.....	400	400
Percent Recovery.....	98.0	98.0

Temperature (FL-2) engine tests which also indicated complete freedom from objectionable reactions due to the inhibitor.

In addition to the effect on initial quality, the effect of Santolene C on storage stability of inhibited products was studied. All tests indicate that this additive has no detrimental effect on the stability of any fuel.

Selection and Preparation of Vessel Used for Trial

Based upon the laboratory tests, it was decided to apply this method of treatment to a vessel. This ship normally sails between Gulf and Atlantic coast ports, making the round trip in about two weeks, although shorter trips frequently are made. It carried clean products north and returned with salt water ballast. This ship was prepared during a drydocking period for the Santolene C inhibitor test. No. 5 and No. 6 port, center, and starboard tanks were cleaned in the usual manner and all loose scale removed from the tanks. A strip or panel, two feet wide, extending along the underside of the deck, down one bulkhead and across the bottom, was sandblasted clean of all rust and scale. This blasted area was provided as a means of showing visually the effect of rustproofing and to determine whether or not the treatment was effective on both clean and previously rusty plates. In addition it was expected that differences in rates of rusting would be very difficult to notice over a short period of time on previously rusty steel. Other than the sandblasted panels, the balance of each tank was left in the condition normally expected after eight years in clean oil trade.

A test rack, containing small coupons 6 inches x 1 inch x 1/4-inch and prepared from low carbon steel, was fastened at top, middle and bottom locations on the ladder.

The only other special feature was the inhibitor injection system. This was merely a heavy gauge 30-

gallon drum which was fitted with a sight glass to indicate the liquid level, a connection for compressed air and a 1/2-inch line extending from the bottom of the drum to a point a few inches from the discharge end of the product filling lines in each tank. Knowing the loading rate and the amount of inhibitor required, a valve on the pressured inhibitor drum was used to inject the inhibitor into the loading line relatively uniformly. The sight glass provided a check on the rate of addition. The inhibitor drum was filled by buckets from the inhibitor supply in the shelter deck. Since only two tanks, No. 5 and No. 6 center, were being inhibited at the selected dosage of 12 pounds per thousand barrels, approximately 1.75 gallons of inhibitor were added per thousand barrels using this system.

To determine the effect of the inhibitor on both ballasted and unballasted tanks, the No. 5 center tank was kept empty of ballast at all times while No. 6 center tank was ballasted after each cargo. To determine the relative effect of the inhibitor on rustproofing by direct comparison, No. 5 starboard and port tanks were used for uninhibited and unballasted service, while the corresponding No. 6 starboard and port tanks were used for uninhibited cargoes and ballast. In this manner it was possible to evaluate the effects of the inhibitor on clean and previously rusty steel, in the presence and absence of salt water ballast, under nearly identical conditions of service.

The Actual Test

During the first nine months of this test a total of 29 cargoes was carried, broken down as follows:

Gasoline	15
Kerosene	3
Furnace Oil	3
Gasoline-Diesel fuel	3
Gasoline-Kerosene-Furnace Oil	4
Kerosene-Furnace Oil	1

29

In each cargo, 12 pounds of inhibitor were added to each 1000 barrels in No. 5 and No. 6 center tanks. After each cargo the No. 5 center, starboard, and port tanks were left empty while the No. 6 center, starboard, and port tanks were ballasted, essentially full. During this period of time it was necessary to wash or Butterworth these tanks ten times in order to change the grade of oil to be carried. No special handling or washing procedures were used in the inhibited tanks. They were treated exactly like their mates as far as possible.

During this 9-month period detailed records were kept as to the barrels of cargo and ballast carried, the amount of inhibitor added, the dates of loading and unloading as well as the temperatures of the product and ballast at the time of loading and unloading. A record was kept also of the number of buckets of rust removed from the tanks at the intermediate cleaning periods.

TABLE VII—Rust Removed from Tanks During Inhibitor Test
(5-Gal. Buckets)
Nine months after cleaning at beginning of test

Tank No.	Port	Center	Starboard
2	64	170	120
3	84	133	128
4	52	67	103
5	43 (No ballast)	58 (Inhibited, no ballast)	56 (No ballast)
6	37 (Ballast)	102 (Inhibited, ballast)	95 (Ballast)
7	44	93	90
8	103	101	55
9	99	129	93

Total number of buckets: 2119.

Total weight of rust: 153,000 lb.

TABLE VIII—Visual Inspection Report on Tanks After Nine Months of Inhibited Cargo

General appearance	No. 5 Unballasted		No. 6 Ballasted	
	Port and starboard	Center inhibited	Port and starboard	Center inhibited
Non-sand-blasted panel..	Considerable rusting with hanging scale	Better than normal, relatively little hanging scale	Quite rusty	Poorer than No. 5 center, but better than normal and better than No. 6 starboard or port tanks
Sand-blasted.....	Rough, rusty. Some tubercles and pits forming	Light rust. Readily removed with rag. Smooth undersurface, no pitting. Condition deemed excellent	Quite rusty with pits and scale forming	Rusty, no scale. Fairly good appearance. Some small, moderately hard tubercles.

Results

After a total of nine months of normal operation, this ship was given its customary drydock inspection and repair. All of the tanks were made gas-free and cleaned. Table VII shows the amount of rust, as measured in 5-gallon buckets, removed from the tanks under test. It should be stated that this ship had been involved in a fire prior to starting this test and considerable new plate had been installed on the port side above the water level. This is believed to be a partial explanation as to why the port tanks contained less loose rust since the new plate had not rusted sufficiently to form the voluminous loose scale which normally would have dropped to the bottom of a tank.

It would appear that the inhibitor effectiveness is not too clear on the loosening of rust. This is in line with findings to be reported later which indicate that it is the rust which was already present at the beginning of the test which is continuing to fall off. Until this old rust has been loosened and removed from the tanks under test, it will be difficult to obtain any worth-while data.

After a visual inspection, the interior of the tanks was found to be as indicated in Table VIII. It was concluded that, although rust formation was evident in all of the tanks, the inhibitor had caused a marked improvement, particularly in the unballasted center tank No. 5. Even with the ballast, as in the No. 6 center tank, the inhibitor appeared to be materially reducing the rate of corrosion.

An inspection of the new plates installed on the port side in the way of the uninhibited tanks indicated that the steel was rusting rather badly; small tubercles and pits were forming and the amount of new rust formed was very comparable to that of the sandblasted panels in the same vicinity.

An adequate description of the interior condition is extremely difficult to convey and depends mainly upon comparison with adjacent tanks and experience with the interior conditions of vessels in similar trades.

Inspection, however, showed that the previously cleaned steel panels had a very light coating of rust which readily could be removed by wiping with a rag. Those who inspected the vessel were extremely enthusiastic on the basis of the obvious reduction in rusting which had been experienced.

A study of the ballast water samples taken during each voyage did not reveal any significant information. The cargo samples, however, definitely showed that the rustproofing qualities of the inhibitor had been maintained. This comparison was made by subjecting samples of the loaded tanks at point of origin to rusting tests in parallel with similar samples obtained during the discharge of the cargo at destination. This would indicate that the rustproofing qualities of fuel

have not been diminished materially and it is possible that rustproofing of subsequent lines, tanks, and equipment may be experienced. This feature, however, has not been investigated sufficiently to date and will not be covered in this report.

Test Coupons

The carbon steel test coupons were removed at three different periods, of 6, 9 and 13 months. The 6- and 13-month samples were from the middle and bottom locations in each tank. The 9-month samples were from the top of each tank and were not uniformly covered with cargo or ballast and these data did not appear to be significant and are not reported herein. The data on the 6- and 13-month periods are shown in Table IX.

It appears that approximately a 50 percent reduction in rusting has been obtained. It also is indicated that the presence of ballast water makes little difference in the rate of rusting, at least in so far as this inhibitor is concerned. It further appears that the corrosion or pitting of the strips proceeded to a given value and then tended to level off. This may be related to the frequency of sea water washing. Additional coupons remain in the tanks, to be removed at a future date and these may give further data which may throw additional light upon the mechanism and intensity of rust formation with extended service.

Costs

At the rate of 12 lb./1000 barrels of inhibitor injection, the protection of the 18,000 barrels of No. 5 and No. 6 center tanks would be in the neighborhood of \$1600.00 for the 9-month period of this test. Calculated on a yearly basis for a T2 tanker, this would be approximately \$14,000.00 per year. In addition to direct costs, a saving in tank washing and cleaning time would doubtless be associated with the reduced rate of rusting. These costs appear to be more than sufficient to justify additional trials in view of the \$50-75,000 per year previously mentioned cost of steel replacements.

Conclusions

From the very favorable appearance of both the rusted and cleaned portions of the ballasted and unballasted tanks; from the possible reduction in the

TABLE IX—Inspection Report of Carbon Steel Specimens from Cargo Tanks

Tanks used	No. 5 port No inhibitor No ballast ¹		No. 5 center Inhibited No ballast ¹		No. 6 port No inhibition With ballast		No. 6 center Inhibited With ballast	
Length of time strips exposed, months ¹	13 ²	6 ³	13 ²	6 ³	13 ²	6 ³	13 ²	6 ³
Weight losses, gm ⁴	10.10	4.27	5.25	9.30	9.89	4.22	4.79	0.0022
Inches penetration/year	0.0047	0.0044	0.0024	0.0097	0.0045	0.004	0.014	0.014
Maximum pit depth	0.026	0.016	0.014	0.026	0.022			
Percent reduction in corrosion by use of inhibitor		Approx. 50%	Approx. 50%			Approx. 50%	Approx. 50%	

¹ Hot sea-water washes were used in these tanks as well as in the ballasted tanks.

² Strips from bottom of tanks.

³ Strips from center of tanks.

⁴ On strip weighing about 180 grams. Size strip, ¼ in. x 1 in. x 6 in.

amount of scale removed from the inhibited tanks, particularly after equilibrium conditions are established; from the 50 percent reduction in rusting shown by the test coupons and from the very low cost of such a method of protection, it has been decided that this test is to be continued and larger scale trials made on other similar vessels. One such trial is being made at one-half the dosage reported herein, or 6 lb./1000 barrels, since laboratory tests have indicated little, if any, difference in rust prevention with dosages over 2 to 3 lb./1000 barrels.

It would appear that an invisible mono-molecular film has been laid down successfully on the steel during the transportation of the cargo and which is retained until the subsequent loading. The over-all rate of corrosion apparently has been retarded materially.

In reviewing the foregoing approaches which have been made towards retarding corrosion in the cargo spaces of tankers carrying refined products, it appears that much valuable work has already been

done in an endeavor to cope with this costly problem. The approaches heretofore have had two serious objections: first, the necessity for the setting up of a mechanical apparatus within the cargo spaces or on deck and its ultimate upkeep and, second, the introduction of the human element in supervising these installations.

It is believed that the introduction of an inhibitor with the cargo represents not only a more positive method but appears to be economically more attractive to the industry. This inhibitor injection might eventually become an operation which could be handled at the refinery and thus relieve the ships' personnel from all responsibility for its application.

Through the introduction of such oil soluble inhibitors into mixed clean oil cargoes, it appears that a practical method for reducing materially the serious internal rusting of tankers has been developed and we hope this method may open up a new avenue of approach and may lead to the development of more efficient inhibitors in the near future.

Part 3. Corrosion Control in Practice

By A. B. KURZ

Topical Outline

- Introduction
- Owner's Requirements for a Corrosion Control Program
- Research Development on the System Proposed
 - Test Procedure and Measurement of Corrosion Rates
 - Chemical Inhibition
 - Galvanic Protection
- The Full-Scale Application of the Corrosion Control Program
 - A. Operating Procedure—Ballast Tanks, Anode Fitted
 - B. Operating Procedure—Non-Ballast Tanks, Chemically Treated
 - 1. The Spray System
 - 2. Ingredients
 - 3. Mixing of Chemicals
 - C. Fleet Indoctrination and Training
 - 1. Instruction Manual
 - 2. The Corrosion Coordinator
 - 3. Records
 - (a) Corrosion Control and Tank Cleaning Report
 - (b) Samples
 - (c) Corrosion Control Summary
 - (d) Summary of Sea Water Dilution
 - (e) Metal Thickness Survey
- New Developments and Possibilities
 - A. The Gas Exhauster
 - B. Water Jet Eductors
 - C. Additional Anodes

Abstract*

Part 3. Corrosion Control in Practice. Application of a full corrosion control program to a fleet of tankers is described. Aiming at a 50 percent reduction in corrosion losses operators instituted the following:

1. Made extensive tests with several methods of corrosion mitigation, abandoning those found to be unsuccessful. Carried on a testing program in one of its ships to determine what methods could be used successfully.

2. Installed magnesium anodes in certain tanks and arranged that these tanks be carried in ballast.

3. Arranged to spray a mixture of sodium nitrite and caustic soda in fresh water into cargo holds not fitted with anodes.

4. Institute an educational program and arranged for periodic reports and tests of the efficiency of the program and the results being achieved.

Evaluation of the corrosion preventing measures adopted indicated substantial and worthwhile success was being achieved. Investigated the areas where excessive corrosion still was being experienced. Many minor changes in procedure were adopted from time to time whereby the crew workload was reduced and the efficiency of the application improved.

(*Note: This abstract was not part of the original publication of Part 3.)

- D. Combination Chemical Mixture
- E. Addition of Wetting Agent
- F. Special Mixing Tank
- G. General

Conclusions

Acknowledgments

References

Introduction

IN ASSEMBLING the thoughts and preparing a particular record of the development and experience of corrosion control for presentation in this paper, the author recognized the marked similarity of this problem to many other shipbuilding problems. An idea or problem is given to the Design or Technical Department for development and after the analysts resolve and evaluate the problem, it moves on to the Production or Operating Department.

Numerous papers and books have been written on the general subject of tanker corrosion—its severity, cost, and waste—and the fundamental theories and cures also have been recorded. It is the purpose of this paper to present basically the operating side of the problem; to set forth a tanker owner's and operator's development work in arriving at a suitable program, and the application and follow-up on vessels operating in coastwise clean mixed product service.

Corrosion control programs of various types have been tried by a number of operators over the last 25 years. However, most of these programs have been tried on a single ship basis, and further, have been confined to a particular tank, and even to a single plate or bulkhead. This paper represents the experience to date of what is considered to be the first full-scale fleet application of a systematic corrosion control program. First, it is hoped that it will acquaint other tanker operators with the progress that has been made and some of the results accomplished by study and hard experience.

Secondly, for the designer, the metallurgist and the researcher interested in this problem, it is intended to show how a corrosion control program must fit into the normal operating schedule of a tanker and how, if it is to be carried out successfully, it must simplify the daily work of the ship's force.

Owner's Requirements for a Corrosion Control Program

Every operator of tankers carrying mixed clean products is familiar with the severity of the corrosion attack upon cargo tank interiors, Figures 6-12. It is known, for example, that a ship operating in clean service has a corrosion rate approximately twice as great as a tanker in black or dirty oil service. Other factors affecting the corrosion rates have been set forth in other papers presented at this symposium.

When my principals set out to look for a corrosion control program for a T2-SE-A1 type tanker in clean coastwise service, their requirements were analyzed. This analysis indicated that a suitable program had to meet certain minimum specifications, among which were:

- A. The achievement of a reduction in corrosion rates in both ballast and non-ballast tanks of at least 50 percent, based on practical shipboard tests.
- B. A program which would not unduly disrupt the ship's normal routine, would not require additional port time, additional sea time, or extended periods in shipyard for installation or maintenance.
- C. The cost of the program must be low. In simple terms, it must be considerably less than a conservative estimate of the savings to be achieved.

- D. Materials to be used in the proposed program must be readily available at key ports, easily handled and not subject to deterioration or breakage.
- E. The program should, if possible, effect a reduction in the over-all work load of the ship's force. The cooperation of the ship's crew was considered most essential. Only a program which would reduce the work load could be expected to receive their wholehearted enthusiasm and cooperation.
- F. Safety was a vital consideration, as it is in all shipboard operations. The corrosion control program, and the equipment used, must be acceptable to the United States Coast Guard, the American Bureau of Shipping, and to the standards of the owner.
- G. Finally, there must be no restrictions on the ability to make the numerous changes in cargo stowage normally involved in multiple product clean service. If possible the allocation of cargo compartments from one product to another, on last minute notice, should be facilitated.

Research Development on the System Proposed

Having in mind the seven points outlined above, Keystone Shipping Co. looked carefully into the program which was recommended by Shell Oil Company, who had considerable experience with corrosion control in the pipeline field.

Two fundamental methods for corrosion control were suggested for simultaneous application:

1. Chemical inhibition of non-ballast tanks using a special solution of an inexpensive, but effective, corrosion inhibitor.
2. Galvanic protection of ballast tanks using magnesium anodes.

It will be noted that this procedure involves the permanent segregation of tanks between those which carry ballast and those which do not.

After considerable theorizing on the practicability of the application of these two principles, it was recognized that there was a possibility of their meeting most of the above requirements.

Test Procedure and Measurement of Corrosion Rates.

The test procedure was as follows:

Test and control tanks were allocated for each method of corrosion control. Normally these were the two wing compartments of the same numbered tank so that both compartments would handle the same product on each voyage. Panels of small test plates cut from ship's steel, Figure 13, were installed at three levels in each tank—near the top, at mid-height and near the bottom.

To measure the corrosion rates, one test plate from each location in the test and control tanks was removed at intervals of about 70 days for measuring, weighing, and analysis in the laboratory. Subsequently, the reduction in corrosion rates which were revealed indicated the comparison between the corrosion rates of the test plates from the test tanks with those removed from the control tanks. All test plates were located, observed, removed and measured by a qualified engineer.

Chemical Inhibition. The T2-SE-A1 tanker *S.S. Cherry Valley*, transporting clean products in coastwise service, was allocated as a test ship. Test plates were installed in selected tanks of the *S.S. Cherry Valley* about six years ago, and experiments started on the

following ballast voyage. No. 3 port tank was assigned as a non-ballast tank for chemical treatment, No. 3 starboard tank was assigned as a control tank to be Butterworthed in the usual manner. Both sandblasted and prerusted test plates were used.

For the initial tests in non-ballast tanks the inhibitor was introduced in the Butterworth stream and applied to the interior of the test tank. Sodium silicate, 5 percent by weight mixed with cold *salt water*, was the first inhibitor tried, the premise being that the silicate would combine with the scale on the tank side to form a protective coating. After a 70-day period, analyses of the test plates indicated that the rate of corrosion in the tanks treated with the silicate solution actually had been increased rather than retarded. Therefore this treatment was abandoned.

The next step, based on laboratory tests, was the use of a *fresh water* solution of sodium silicate. This introduced an entirely new concept into the procedure for washing and cleaning of ships' tanks, as it previously had not been considered feasible to carry a sufficient amount of fresh water for this purpose. However, it was known that the use of fresh water rather than salt water would, in itself, result in a reduction in corrosion rates, quite apart from the use of an inhibiting solution. To conserve the amount of fresh water and inhibitor, a recirculation system was worked out using ship's cargo pumps and piping. The method evolved was to load 150 barrels of fresh water in an after cofferdam at the discharge port. The fresh water subsequently was transferred to a wing compartment where the sodium silicate was introduced to form the desired solution. Suction was taken from the wing compartment and the solution was pumped through a deck line to the Butterworth machine in the tank to be treated. Another pump was used to strip the solution from the treated tank, discharging it back to the mixing tank. The amount of water used was sufficient to allow for a thirteen-minute settling out period. This provided effective separation.

This system required no special equipment. The test tank was washed first for one half hour with fresh water, then Butterworthed for a full hour with the 5 percent silicate solution. About a year later it was apparent that a definite reduction in the rate of corrosion had been achieved. However, there were indications that the preliminary fresh water wash had the effect of washing off the residual silicate deposit on the tank surfaces. Therefore, a change in the method of application was made whereby the tanks were washed for one and one half hours with the silicate solution alone, except that fresh water was used initially for displacing any product that happened to be in the ship's cargo pipelines.

During the cold weather months of 1948 difficulty was experienced in applying the silicate solution due to its propensity for fouling the Butterworth machines. In March 1948 a new type sprayer was substituted for the Butterworth machine. The new sprayer was designed to provide for the continuous wetting of the interior surfaces by means of a fine spray at a comparatively low pressure. After 490 days of silicate treatment, it was considered that

TABLE X

	Corrosion Rate, mils/year		Reduction in Corrosion Rate
	Test Tank No. 3 Port	Control Tank No. 3 Starboard	
Weight loss corrosion.....	6.65	10.15	34.5%
Pit depth corrosion.....	15.15	17.85	15.2%

TABLE XI—Corrosion Rates—
Chemically Inhibited Non-Ballast Compartments

	After Initial Protection	Reduction in Corrosion Rates
Weight loss corrosion rates.....	3 mils/year	80%
Pit depth corrosion rates.....	11 mils/year	50%

sufficient experience had been obtained. The over-all results during the period under test are shown in Table X.

These figures indicate the average rate of corrosion over the period. Actually, there was a considerable variation in the rates experienced during the various test periods. As was to be expected, the higher rates corresponded with maximum gasoline shipments and the lower rates with distillate shipments.

The results achieved by the sodium silicate method were not considered to be sufficiently effective to warrant its adoption and therefore it was recommended that the inhibitor be changed to sodium nitrite. This represented the next major step in the development program.

The sodium nitrite test treatment was started on the S.S. *Cherry Valley*, and new test and control tanks were allocated—No. 8 port was designated as the test tank, and No. 8 starboard, the control tank. Sodium nitrite was chosen as a result of favorable indications obtained in a side experiment made in the No. 2 port, center and starboard tanks for descaling purposes. The solution consisted of a 5 percent by weight sodium nitrite fresh water solution, containing a solution of one half of one percent by weight flake caustic, which was increased a few months later to one percent. The function of the caustic is to insure that the solution is very alkaline. It also helps to remove the residual oil and therefore permits contact between the nitrite and the steel.

Basically, this solution was applied with the same spraying procedure as the earlier silicate solution. However, the split cycle recirculation system was replaced with a direct recirculation system in which one of the stripping pumps took suction from the test tank and discharged directly back through the deck line into the sprayer. The test tank was treated on each ballast voyage and at the end of the treatment the nitrite solution was pumped overboard at sea. The control tank was washed for one hour with cold salt water.

The chemical inhibition of non-ballast compartments develops a relatively thin, firmly adhering protective coat of oxidation, which, through the inclusion of nitrite and caustic, effectively controls corrosion on the surfaces coated.

Analyses of the S.S. *Cherry Valley* test plates, and the record of physical change within the test compartments, indicated that:

- A. Approximately one and one-half to two years would be required to remove heavy scale and to achieve ultimate protection within non-ballast compartments.
- B. After the old scale is removed, they will not be subject to recurring build up and deterioration and the corrosion rates should be reduced as shown in Table XI.

Galvanic Protection. The galvanic protection of cargo tanks is achieved by the electrochemical action of iron and magnesium immersed together in salt water ballast as the electrolyte. After having received the approval of the United States Coast Guard, the first installation of magnesium anodes was about six months following the start of the chemical inhibitor trials. It should be pointed out that during the waiting period a ballast tank, No. 6 port, was treated with a sodium silicate wash, both before and after loading and discharge of ballast, but in neither case did it indicate any effective control of corrosion.

The anodes were installed in the No. 4 port and starboard wing tanks. Eight anodes, bolted to the ship's structure with insulating bars, were fitted in each compartment. The only difference in the treatment of these two tanks was that No. 4 port tank was treated with a cold sea water wash after discharge of ballast, while the starboard tank was Butterworthed with hot sea water. No. 6 starboard tank, which was used as the control tank for chemical inhibition before ballast, also was suggested as the control tank for the anode experiment in No. 4, port and starboard tanks.

The magnesium anodes used for this purpose have the dimensions and chemical composition shown in Table XII.

By December 1947 the test plates in the ballast tanks showed that there had been an encouraging reduction in the rate of corrosion, but the effect appeared to be localized in the immediate vicinity of the anodes. Therefore, as a means of accomplishing a more effective coverage, it was decided to increase the number of anodes in each tank to 18 and install them on a framework, fitted within the tanks. Previously, inspection revealed that a considerable amount of scale had been removed from the tank and it was noted that a protective coating of calcareous salt had been deposited in the areas that were bare of scale. As additional scale was removed from the structure of the tanks, an increase in the rate of magnesium consumption was noted, Figures 14 and 15.

Four additional anodes were fitted in No. 4 port tank in July 1948. In November 1948 an additional 15 were added, bringing the total number of anodes in No. 4 port tank to 37 as compared with 18 in the starboard compartment. The effect of the anodes, as measured by the test plates over a period of 410 days, indicated that they were providing an effective control of corrosion in ballast tanks, the average wastage having been reduced approximately 49 percent, Figure 16. Since galvanic protection is dependent

on the alkaline calcareous salts, the necessity of eliminating the destructive impact force of high velocity streams of water was apparent. In consequence, the normal Butterworthing of these tanks was eliminated.

Having achieved protection, corrosion should not be subject to fluctuation of rates which follows the build up and removal of scale within unprotected compartments. The results of the action of magnesium anodes in No. 4 port tank as compared to the ballast control tank, No. 6 starboard, were as shown in Table XIII.

By the spring of 1949 a total of 180 test plates from all test and control tanks had been removed and analyzed, and the results plotted, indicating that these two methods, properly applied in full-scale operation on a single ship, could effect a reduction in corrosion rates of between 60 percent and 80 percent.

For the purpose of obtaining accurate costs, full-scale specifications were drawn of a fixed chemical spray system in non-ballast tanks, and plans and specifications were prepared for the installation of framing on which to hang the magnesium anodes in the tanks allocated to salt water ballast. These specifications were submitted to ship repair yards capable of accomplishing such work. The bid results indicated that the magnesium anodes could be purchased and installed in ballast tanks of a T2-SE-A1 tanker, and the spray system installed in non-ballast tanks, for a total of approximately \$30,000. Incidentally, the finding of a suitable spray nozzle, and the designing of the spray piping system, involved considerable time and research.

Keeping in mind the owner's requirements of a corrosion control program, the records from the test plates of this 2½-year development readily indicated that these methods could accomplish the desired reduction in corrosion rate, the operation fitted the ship's variable scheduling, the cost was reasonable, the chemicals and equipment were readily available and further encouragement came from the realization that the program would reduce the normal work load of ship's personnel. Eventually it should improve the safety factor aboard tankers—primarily in the reduction of manual tank cleaning operations.

It was recognized that the combination of hot salt water and a steel surface provided an ideal condition for excessive corrosion and it was most desirable that

TABLE XII

Dimensions.....	4 in. x 4 in. x 36 in.
Weight.....	45 pounds (approx.)
Chemical Composition.....	Percentage
Aluminum.....	5 to 7
Zinc.....	2 to 4
Manganese.....	0.10 Max.
Silicon.....	0.3 Max.
Copper.....	0.10 Max.
Nickel.....	0.003 Max.
Iron.....	0.003 Max.
Total Others.....	0.3 Max.
Magnesium.....	Remainder

TABLE XIII—Corrosion Rates in Galvanically Protected Ballast Compartments

	After Initial Protection	Reduction in Corrosion Rates
Weight Loss Corrosion Rates.....	3 mils/year	70%
Pit Depth Corrosion Rates.....	9 mils/year	60%

GUIDE FOR TANK CLEANING PROCEDURE						
When changing from Cargo to	A	B	C	D	E	F
A	Strip tanks dry. Keep hatches closed	Strip tanks dry. Keep hatches closed	Strip tanks dry. Keep hatches closed	Strip tanks dry. Keep hatches closed	Strip tanks dry. Gaudre, with air ejectors if fitted	Strip tanks dry. Gaudre, with air ejectors if fitted
B	Strip tanks dry. Keep hatches closed	Strip tanks dry. Keep hatches closed	Strip tanks dry. Keep hatches closed	Strip tanks dry. Keep hatches closed	Strip tanks dry. Gaudre, with air ejectors if fitted	Strip tanks dry. Gaudre, with air ejectors if fitted
C	Butterworth cold	Strip tanks dry. Keep hatches closed	Strip tanks dry. Keep hatches closed	Strip tanks dry. Keep hatches closed	Butterworth cold	Butterworth hot
D	Butterworth cold	Strip tanks dry. Keep hatches closed	Strip tanks dry. Keep hatches closed	Strip tanks dry. Keep hatches closed	Butterworth cold	Butterworth hot
E	(See note)	Butterworth hot (see note)	Butterworth hot (see note)	Strip tanks dry. Keep hatches closed	Strip tanks dry. Keep hatches closed	Butterworth hot
F	Strip tanks dry. Keep hatches closed. Vapors ejected	Strip tanks dry. Keep hatches closed. Vapors ejected	Strip tanks dry. Keep hatches closed. Vapors ejected	Strip tanks dry. Keep hatches closed. Vapors ejected	Strip tanks dry. Keep hatches closed. Vapors ejected	Strip tanks dry. Keep hatches closed

Note: "A," "B," & "C" not normally loaded after intervening cargo of "D" will be used. Switching from "E" to "A" only with special permission and given specific cleaning procedure

Figure 17—Guide for tank cleaning procedure

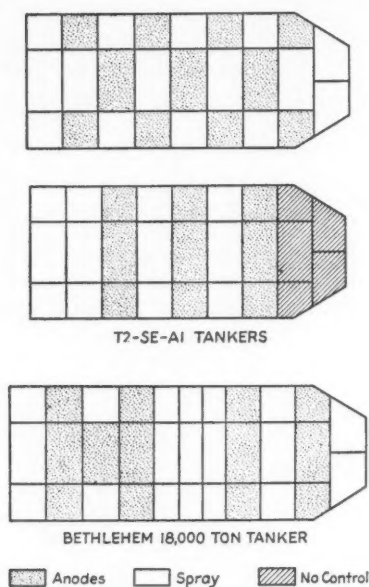


Figure 18—Corrosion control—arrangement in cargo tanks.

Butterworthing be modified or dispensed with where possible.

A requirement of corrosion control methods, when applied to ships operating in clean multiple product service, is that they provide sufficient cleaning action to enable a change to be made between any two clean products without danger of contamination. If, when changing from one product to another, the normal cleaning method of Butterworthing with hot sea water was used, the effectiveness of corrosion control would be reduced greatly. In ballast tanks, tests proved that changes between any two clean products could be made without fear of contamination merely by hosing out and stripping tank bottoms before ballasting. In non-ballast tanks the spraying of the inhibiting solution provides adequate cleaning. The ability to change between any two clean products in a ballast tank with only a hand hosing of the bottom and the washing effect of clean sea water ballast is due to the removal of most of the scale by the action of the magnesium anodes. The scale, like a sponge, normally holds a considerable amount of residual product.

A guide for tank cleaning, which reflects this re-

duction in Butterworthing requirements, was developed and immediately put into effect on a fleetwide basis, Figure 17. This is the primary factor in reduction of the ship's force work load.

The Full-Scale Application of the Corrosion Control Program

The results, both visual and factual, of the 2½-year experiments aboard the S.S. *Cherry Valley* with the chemical inhibitor and the galvanic protection, created enough confidence for the owners to authorize the installation of these systems in the cargo compartments of five T2-SE-A1 type tankers operating in clean service in the Atlantic coastwise and the Pacific coastwise trades. Only by such a full-scale application can the actual results and real value of corrosion control be evaluated.

Having made this decision, it was necessary to assign specific cargo compartments to either ballast or non-ballast service. Such assignments had previously been left to the discretion of the master, and thus, were subject to considerable variety. The factors considered in determining this standard assignment were:

- Proper trim of the ship.
- Ability to check compartments for bulkhead leaks.
- Proper load distribution to minimize stress concentrations.
- The complex scheduling of cargoes.

Primary consideration was given to the ballast tanks because the galvanic protection required no operational features, thus emphasis was placed on galvanic control and having as many ballast tanks as practical.

It was decided that sufficient ballast, properly distributed, would be loaded on each voyage to bring the ship down to marks suitable for relatively heavy weather, resulting in an average T2 draft of 20 feet forward and 25 feet aft. This involved handling more ballast than had previously been the practice. However, that was more than offset as the fuel and steam required for Butterworthing operations had been substantially reduced, and the net effect was improved performance.

The other factors were of relatively minor consideration and after the trim and distribution factors had been resolved, the ballast plan took the form of two general patterns, either of which met all of the four factors. These have been classified as

- The athwartship pattern.
- The checkerboard pattern (Figure 18).

Both of these systems are employed on separate ships.

Experience to date leads to the belief that the most desirable pattern is the athwartship pattern, because, in many cases, longitudinal bulkheads have fractures or weld failures and the salt water ballast, either in the center tank or the wing tanks, will penetrate the longitudinal bulkhead into the adjacent empty tanks and thus have the effect of diluting and contaminating the chemical inhibitor. It may be argued that the system creates some additional local stress on the

longitudinal bulkheads which results in structural failures in the form of fractures.

The total number of anodes installed was increased to 51 in a T2 wing compartment and 74 in a center compartment. The manner in which the anodes were distributed throughout the cargo tanks on a special framework is illustrated in Figures 19, 20, 21, 22, 23 and 24.

Obviously, after the assignment of ballast tanks, all of the remaining tanks automatically were classified as non-ballast tanks to be equipped with a fixed spray system for the chemical inhibitor.

A. Operating Procedure—Ballast Tanks, Anode Fitted.

In addition to the specific assignment of tanks as regular ballast compartments, a new procedure had to be initiated to meet the requirements. Immediately upon departure from the discharging port, each ballast tank is hand hosed with a salt water hose from the cargo tank access hatch for a period of approximately five minutes. The purpose of this flushing operation is to remove any residual cargo or muck. After all of the tanks have been stripped of slops into a slop tank, the ballast tanks are filled with clean sea water. It is important that each ballast tank be filled into the access hatch to obtain the maximum benefit and insure treatment of the underside of the upper deck.

Special procedure was necessary for vessels sailing from fresh water ports, such as Albany, N. Y., or Portland, Ore. While it would normally be considered desirable to take on fresh water ballast, it was recognized that fresh water would not be as effective an electrolyte as sea water. Therefore, a minimum amount of fresh water ballast was taken from such ports, and after departure at sea, fresh water ballast was replaced with sea water. This procedure was considered necessary only during the first year after the installation of the anodes.

The time required for loading and discharging of ballast was committed to the individual master's judgment, to be so coordinated that maximum benefits would be received from the corrosion-retarding anodes without loss of transportation time.

B. Operating Procedure—Non-Ballast Tanks, Chemically Treated.

1. The Spray System.

The fixed spray system installed in the non-ballast tanks consists of twelve nozzles in each center tank and twelve nozzles in each wing tank, spaced so that maximum coverage is accomplished with uniform velocity and low impingement force, Figures 25-29. The nozzles used are $\frac{3}{4}$ -inch with a $\frac{1}{4}$ -inch orifice fitted with a single fixed vane, making a spray angle of approximately 92 degrees.

The locations and distribution of the nozzles in the tank interiors are specifically designed to accomplish a thorough wetting of the tank interior surfaces using a minimum volume of solution, as distinguished from the use of high-pressure nozzles creating high striking force and requiring large volumes of liquid.

The fixed piping system is supplied through the stripping pump 4-inch discharge line on deck and the spray in the individual tanks is controlled by valves on the upper deck so that each non-ballast tank may be treated individually.

2. Ingredients.

The delivery of the necessary ingredients is the first step in the operating procedure established for the non-ballast tanks.

- (a) Fresh water is taken at the discharge port in the amount of 150-175 barrels and stored in one of the cofferdams assigned for this purpose.
- (b) Sodium nitrite, in the amount of 2000 pounds, is delivered in five 400-pound drums.
- (c) Flake caustic, in the amount of 1200 pounds, is delivered in three 400-pound drums. Two and one half drums, or 1000 pounds, are used each voyage.

The procedure may be varied from time to time if larger volumes of chemical solution are required for a single operation, or to take on sufficient quantities to meet the requirements of several voyages. On departure from the discharge port the non-ballast tanks are flushed, but with a different medium from the ballast tanks. Fresh water is used for this purpose as salt water would counteract the effects of the chemical solution. The fresh water is sprayed through the fixed nozzle system separately into each compartment and the required period of the flushing depends upon the last cargo carried. Generally one to two minutes are adequate. This quick flush accomplishes the removal of residual cargo from the tank bulkheads and bottom and also removes the sea water remaining in the cargo pipelines following the ballasting operation. To insure that all residual cargo is removed from the stripping line, the most remote tank from the stripping pump is given a five-minute fresh water spray before final discharge of the residual products overboard.

3. Mixing of Chemicals.

A cargo tank fitted with the spray nozzles was used as a mixing tank for the required chemical solution, usually No. 8 or No. 9 port tanks. From the cofferdam storage tank 125 barrels of fresh water were pumped into the mixing tank. To this fresh water in the mixing tank, 1000 pounds of caustic and 2000 pounds of sodium nitrite were added (Figure 31).

Special emphasis was made on the introduction of chemicals after the fresh water had been transferred, to insure easy dissolution.

Tank treatment was commenced, immediately after the satisfactory solution had been achieved, by taking suction from the mixing tank through the 6-inch stripping line to a given tank, through the spray nozzles onto the interior surfaces, and again through the stripping pump for a recycling process of about one hour. A discharge pressure of approximately 80 to 100 psig was maintained to insure the proper spray pattern at each nozzle. Tanks having had light oil cargo were scheduled for treatment first. If heavier

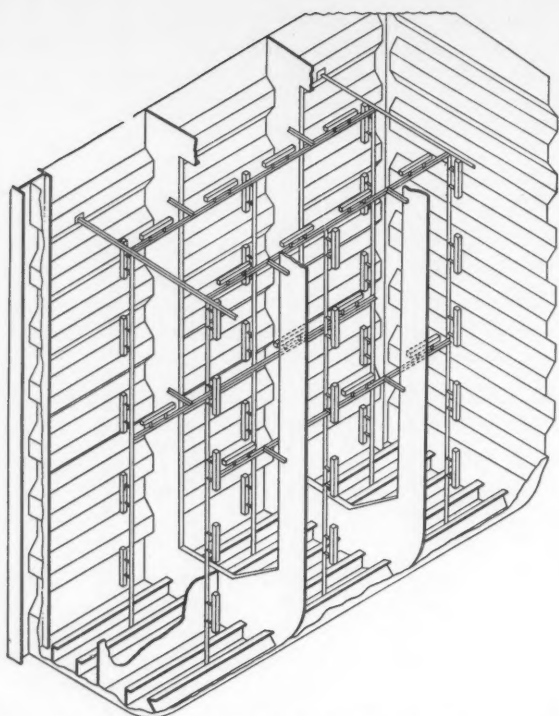


Figure 19—Isometric view—port wing tank—showing location of anodes and supports.

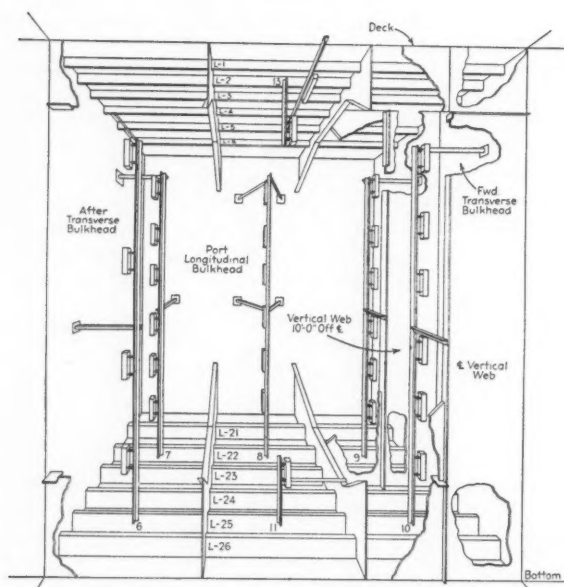


Figure 20—Typical view of center tank—centerline looking to port.

oil had been carried they were scheduled for treatment after the lighter products. This was to maintain the potency of the solution. A special bank of self-flushing type marine strainers on the supply line was provided to trap scale or sediment and provided for its quick removal, Figure 32.

After all of the tanks have been sprayed with the

chemical solution, the expended solution is discharged overboard. Finally, after the spray, the tank hatches were left open to permit aeration of the tank interiors and thus accelerate the removal of scale.

C. Fleet Indoctrination and Training.

The procedures outlined thus far worked successfully on the S.S. *Cherry Valley* under the direct supervision of the corrosion engineer and with the cooperation of the ship's force, who had the benefit of three years' development training. The adoption of the full-scale system on five ships concurrently presented a new problem involving salesmanship, education and training. It is a known fact that ships' personnel are reluctant to change, particularly when physical evidence of improvement is not immediately apparent. They have encountered numerous corrosion experiments, seen them tried, abandoned and forgotten. Recognizing the importance of the complete cooperation of the ships' personnel to the success of this system, a program of training and follow-up was promptly prepared, consisting of:

1. The development of a complete Instruction Manual setting forth all the details of the program, including a brief summary of the corrosion methods and their development, detailed record of the operating procedure and miscellaneous comments concerning requisition of materials, reports and what results could be expected. For example, the rapid falling of large quantities of scale from the ballast tank bulkheads for a period of about ten months until the surfaces are free of scale.

This manual was issued to masters with the instructions that they were to direct personally all phases of the program and charged them with the responsibility of its execution, including the training of officers and personnel.

2. The program represented such a vast change in procedure that the proper adoption would be difficult without personal and direct guidance. It was only by such personal and direct guidance that the record on the S.S. *Cherry Valley* was achieved. Therefore, a corrosion coordinator was chosen to make a ballast voyage on each ship after she was fitted with the complete system. It was his function to transmit to ships' personnel his endorsement and personal acquaintance with the program, and to satisfy himself that they understood the theory and requirements of the program. This was accomplished by actually going through each step of the operation, and subsequently examining the compartments.

Special emphasis was placed on necessary safety precautions. Rubber gloves and special safety goggles, Figure 31, are provided for the use of personnel handling the chemicals as physical contact with flake caustic must be avoided. The sodium nitrite is toxic and should not be taken internally either as a solid or solution. All personnel are instructed to wash thoroughly with fresh water after any contact with these chemicals.

The corrosion coordinator makes regular follow-up trips semi-annually on each of the five vessels so equipped, assuring himself that the program is being followed out, that new methods and procedures have been accepted and are being applied, that new personnel are properly instructed, and finally, to report any deficiencies in the equipment, pipelines, nozzles, or anodes. Several interesting reports are worthy of mention.

One vessel had a perfect record of the submittal of the required samples, but the follow-up check revealed that none of these samples had been taken from the spray system. Rather, the bulk chemicals were discarded overboard and the samples drawn from a small drum mixed specially for that purpose. In another instance, corrosion control activities were delayed until a week end passed in order to minimize any overtime payments. Such reports emphasize the importance of ship's force cooperation and the necessity for on-the-spot follow-up.

3. The administrative procedures for recording events aboard ship and informing ships' personnel were considered an important function in managing and following up corrosion control. The records consist of:

(a) "Corrosion Control and Tank Cleaning Report," Figure 33. This report was adopted from a standard form which is used by most tanker operators. The standard form was a record of cleaning and gas-freeing tanks, which showed primarily how long a tank was Butterworthed and the number of buckets of scale removed from that compartment. The new form is designed to indicate the record of treatment of ballast and non-ballast tanks in specific terms of the amount of ballast and the length of time ballasted. Also the period of time sprayed with chemical inhibitor. The form still retains the Butterworthing and scale removal information. After each ballast voyage the ship submits this form for office use in preparation of summaries.

(b) **Samples.** On each ballast voyage two 4-ounce samples of the sodium nitrite solution are taken, one immediately after the solution has been thoroughly mixed, and the other after all of the compartments have been sprayed. These samples are sent ashore and analyzed for chloride content and serve as a record of the progress of the application of chemical inhibition aboard the ship. Figure 34 shows on the left the glass bottle which originally was used. However, because of breakage in transit, it was replaced with the polyethylene bottle. Both are mailed in the standard container shown in the center.

(c) **Corrosion Control Summary.** The Corrosion Control Summary, Figure 35, was primarily a summary of the buckets of scale removed as taken from the Corrosion Control and Tank Cleaning Report. It also served as a check off on the solution samples sent in by the vessel. When all loose scale had fallen, scale removal became negligible and this form was discontinued.

(d) **Summary of Sea Water Dilution** (Figure 36).

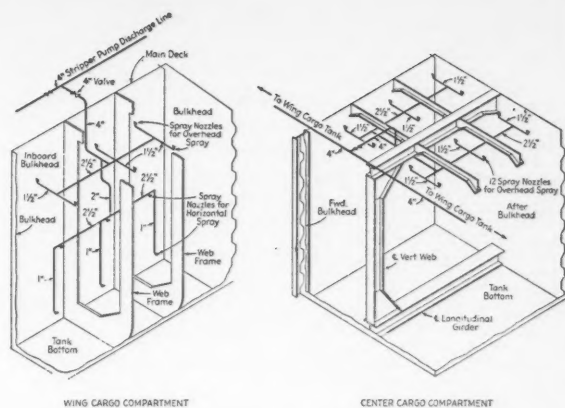


Figure 25—Fixed spray system—aboard a T2 tanker.

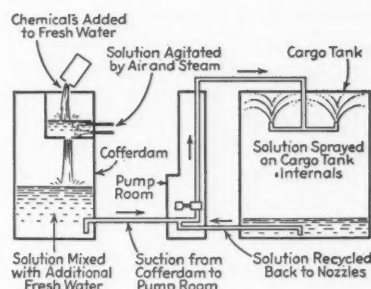


Figure 30—Chemical spray system.

CORROSION CONTROL AND TANK CLEANING REPORT														
S/S	Turned
...
Task No.	Last	Start	Index	Ballast	Chemical	Time	Pressure	Temp.	Fresh	Bottom	Scale	Scale	Scale	Remarks
...
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
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98
99
100
TOTALS

Figure 33—Corrosion control and tank cleaning report.

After the samples are analyzed, each ship receives a report of the analysis of the samples submitted by all ships using the program. Thus, each master knows the efficiency of his operation compared to the others. Sea water dilution is measured in terms of percentage by volume and each master knows that he has a good solution if dilution does not exceed 20 percent.

(e) **Metal Thickness Survey.** With the full-scale application of corrosion control to a ship and to the

fleet it was no longer necessary or practical to record the actual progress by the test sample coupon measurements. It was recognized, however, that experience records would be required to verify the results of the test plate data and to evaluate the full value of the corrosion control program over a long period of time. To develop this experience a metal thickness survey was established, to be taken at each annual overhaul period. Consideration was given to micrometer readings and electronic readings by an Audigage. Because of the number of measurements required, it was decided to adopt the Audigage reading, Figure 37. The metal thickness surveys with the Audigage were commenced on several of the ships in June 1950 and up to the present time all of the corrosion control fitted ships have had a metal thickness survey at least once, and several vessels have had this survey two or three times.

Specific results are recorded on a bulkhead plan for each strake, Figure 38. After all of the results are in, a combined summary is developed and a general curve, or pattern, plotted (Figure 39). These are actual readings taken from all parts of the ship: Bottom, deck, internal structure, bulkheads, etc. The measurements are taken two or three times in each location to verify the reading. On the survey of one T2 tanker, where only one reading was taken at each location, five or six of the plate thicknesses were recorded heavier than original. This established the need for two or three readings. Data taken and collected from the metal thickness surveys are forming the basis for a complete report on the over-all effectiveness of this system. Sufficient data for such a report should be available by 1955, thus allowing a five-year service period.

New Developments and Possibilities

Since the introduction on a fleet-wide basis, there has been continual improvement in the methods and procedures discussed earlier. These new developments have originated with the shipboard personnel from their own experience, and with suppliers who have taken an interest in our use of their materials and they have suggested more efficient methods. The following represent some of the more important changes introduced.

A. The Gas Exhauster. This is a piece of equipment which has been used on tankers for a number of years, in either a portable or fixed position, for ventilating and gas-freeing tanks during emergency tank repairs. It has been adopted especially in this system for the purpose of gas-freeing to permit entrance for bulkhead inspection or to eliminate the possibility of contamination of the next product from residual vapors. It should be mentioned that tank washing operations formerly were used to gas-free and remove vapor.

B. Water Jet Eductors. The removal of scale and muck from tank bottoms long has been a severe and laborious task for the ship's force. The functioning of the magnesium anodes in the ballast tanks caused an almost immediate falling of all loose scale from

CORROSION CONTROL SUMMARY

S.S.		Report for May & June 1951					
Voyage No.							
Samples Mailed							
Harden Report							
Sample No. 1	% Cl	Bennington	Bunker Hill	Cherry Valley	Monmouth	Ticondoga	
	% NaNO ₂						
	pH						
Sample No. 2	% Cl	Bennington	Bunker Hill	Cherry Valley	Monmouth	Ticondoga	
	% NaNO ₂						
	pH						
Copy Harden Report to Ship							
Keystone Report							
Date							
Tank	Treat.	Buckets of Scale Removed . .					
1 P				17	12	17	
1 S				14	10	17	
2 P		54		10	7	20	
2 C		24			11		
2 C P							
2 C S				2			
2 S		68		15	3	17	
3 P				39	56	12	
3 C		153	200	82	65	97	
3 S				45	35	9	
4 P		78		16	15	30	
4 S		70		9	19	21	
4 C			175	13	5	11	
5 P		16	35	48	76		
5 C		58	280	71	22		
5 S		18	37	39	13		
6 P		48	20	11	15		
6 C				9	10		
6 S		51	35	10	41	16	
7 P			100	39	25	8	
7 C		75	300	84	33		
7 S			205	40	36	9	
8 P		94	221	20	10		
8 C			480	20	45	11	
8 S		93	43	23	9		
9 P				5	11	32	
9 C				24	25		
9 S				10	12	7	
Total		894	2131	715	620	475	
Brought Fwd.		6994	3475	673	2043	2499	
Grand Total		7888	5606	7452	2663	2974	

Figure 35—Corrosion control summary.

tank bulkheads. Figure 35 illustrates the number of buckets removed over a 2-month period, 2100 buckets from one ship. In addition to this manual task, stripping-pump valves were chewed up in the scale removal. Another difficulty was the removal of liquid from cargo tanks when two Butterworth machines were operating concurrently. The volume discharged was beyond the capacity of any one stripping pump and a residual film of cargo was left in the tank. The installation of water jet eductors became the solution of these three problems. Eductors were installed in the after pump room, actuated by the main cargo centrifugal pumps and so connected to the ship's cargo piping system that a suction could be taken from any tank. This installation has—first, insured complete stripping of all residual product or ballast prior to treatment, second, reduced wear on cargo pumps as any scale goes overboard via the eductors and finally, has practically eliminated the old mucking out process. With the use of the eductor, the flushing out operation, described earlier for both the ballast and non-ballast tanks, can be accomplished efficiently by the ship's force operating valves on deck with minimum effort.

C. Additional Anodes. The detailed inspection reports indicated the rapid deterioration of the magnesium anodes located near the bottom of the ballast tanks. The dissipation of these anodes indicated a failure to build up and maintain the calcareous protective coating on the steel structure. Perhaps the coating would have been achieved over a longer period of time; however, it was apparent that the

CORROSION CONTROL WITHIN CARGO COMPARTMENTS— KEYSTONE SHIPS

ANALYSES OF FRESH WATER INHIBITOR SOLUTIONS

Ship	Voyage No.	Date	Before Treatment of Compartments			After Final Treatment			Sea water dilution % by volume
			% Chloride by weight	% NaNO ₂ by weight	% Caustic by weight	% Chloride by weight	% NaNO ₂ by weight	% Caustic by weight	
Cherry Valley	180	12/17	0.07	3.4	1.74	13.5	0.19	2.16	13.5
	181	12/29	0.06	3.86	2.04	13.5	0.54	2.14	13.5
	182	1/11	0.10	3.32	1.68	13.5	0.25	2.73	11.7
	183	1/23	0.08	3.08	1.79	13.5	0.64	2.18	13.5
	184	2/26	Sample broken			1.22	1.59	0.67	13.0
	185	2/26	Sample received broken			0.73	3.01	0.84	13.5
Keweenaw	186	12/16	0.24	2.62	1.72	13.5	0.37	1.95	0.97
	187	12/28	0.09	3.15	1.73	13.5	0.26	3.51	1.29
	188	1/11	Sample broken			0.67	3.11	1.4	13.5
	189	1/22	0.10	3.61	0.98	13.5	0.15	3.53	0.77
	190	2/5	0.09	4.45	2.2	13.5	0.28	3.2	1.2
	191	2/17	0.09	4.22	1.84	13.5	0.18	4.22	1.47
Donington	192	2/19	0.55	2.3	1.44	13.5	Sample broken		
	193	12/22	0.33	5.5	2.1	13.5	0.64	3.46	0.90
	194	1/16	0.23	3.2	2.1	13.5	0.48	2.0	0.67
	195	1/26	Samples not received			0.60	2.94	1.1	13.5
	196	2/7	0.10	4.1	1.9	13.5	0.36	3.2	1.3
	197	2/17	0.11	4.2	1.7	13.5	0.17	4.26	1.47
Donington	198	3/1	0.17	5.1	2.0	13.5	0.25	4.3	1.39
	199	3/1	0.17	5.1	2.0	13.5	0.25	4.3	1.39

* After construction of linking tanks.

Figure 36—Summary of sea water dilution.

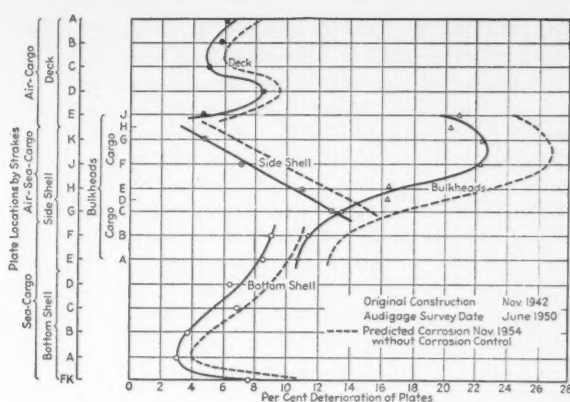


Figure 39—Metal thickness survey curves, S.S. Cherry Valley.

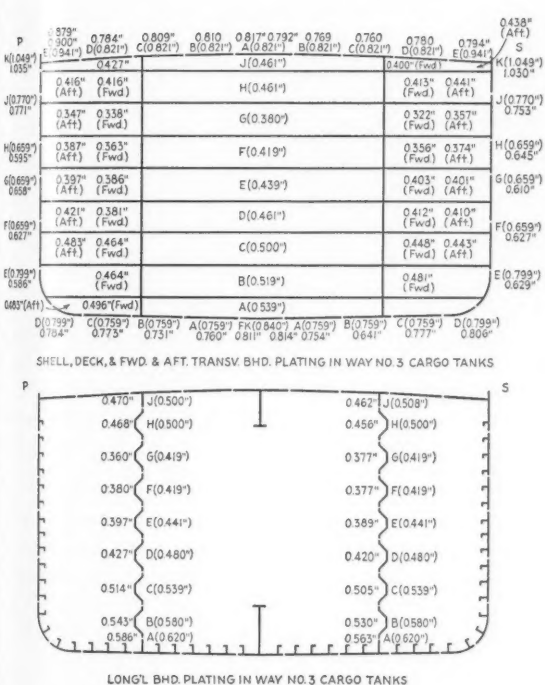


Figure 38—Plate thickness survey—No. 3 tanks—transverse and longitudinal bulkheads.

total area of steel was beyond the effective range of the total number of anodes. Also, the dissolving action of a few barrels of sea water which remain in contact with the bottom plates tends to retard the build up and protective coating. Therefore in February 1952 an additional anode was installed at each bottom location giving the appearance of twin anodes on each bracket and this additional installation should improve the protection in the bottom area.

D. Combination Chemical Mixture. To simplify purchasing, delivery and handling of chemicals on board, arrangements have been made whereby chemicals in flake form will be supplied in one container already

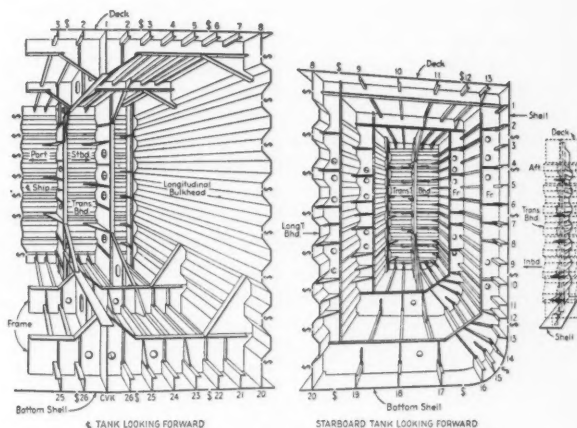


Figure 40—Center and wing tanks—interior structure.

mixed in the proper ratio. This will insure proper proportions at all time and reduce the caking problem which occurred in the sodium nitrite barrels if they were carried on board in damp atmospheres for several voyages. The new mixture will not powder as the present sodium nitrite does and therefore will be less annoying when poured on a windy day.

E. Addition of Wetting Agent. To improve the wetting characteristics of the chemical solution, it was suggested that a wetting agent be added. This has been a recent development and experiments are being conducted to determine the proper amount of wetting agent to be added to the 125 barrels of solution.

F. Special Mixing Tank. The operational experience and analysis of the inhibitor solution and scale remaining in the tanks indicated that the sodium nitrite and flake caustic had not passed into solution as quickly as desired and lumps of the chemical remained in the wing tanks unmixed. Difficulty often was encountered in measuring the exact quantity of fresh water which resulted in an inconsistent mixture. To solve this problem, in June 1952 it was decided to use a portion of the starboard cofferdam as a mixing tank to prepare a concentrated liquid solu-

tion with the fresh water and chemicals. A few minor changes were made in the cofferdam to form a mixing section in the upper portion. Lightening holes were blanked and a drop valve installed for controlling the liquid concentrate. A steam line and a compressed air line were installed to agitate the liquid and to insure that the chemicals passed into solution (Figure 30). When the concentrated solution is mixed it is dropped into the lower cofferdam which contains the amount of water required to form the proper solution. This procedure also makes it practical to drop the chemicals into the cofferdam immediately upon receipt if desired, even though making the solution and agitating the mix is delayed until the vessel is at sea. This has eased the burden of handling the drums twice. The mixing tank should greatly improve the efficiency of the system.

G. General. In May 1952, inspection indicated that the maximum scale deterioration had been achieved by aeration of the non-ballast tanks. The procedure was changed so that all the chemically treated tank hatch covers are kept closed during and after sprays. This will maintain a moist atmosphere. Reports and inspections have shown that all of the nooks and crannies of the interior surfaces of non-ballast tanks, Figure 40, are not being wetted as desired. Estimates indicate that only 90 to 95 percent of the surfaces are being wetted. Total wetting is vital to the achievement of the indicated results. Continued corrosion on the 5 to 10 percent of surface uninhibited results in sufficient wastage to require complete renewals. Therefore, experiments are now being conducted to improve the spray nozzle distribution pattern, either by the use of a new type of fixed nozzle, additional location of fixed nozzles or rotary nozzles.

Conclusions

The enthusiasm and interest with which the corrosion control program has been accepted by ships' officers has been most encouraging and to a large part they are responsible for the successful execution and development thus far.

As previously stated, factual results of the full-scale program will not be forthcoming for several years, but present observations, such as the reduction of scale build up and removal, the dissipation of magnesium as predicted throughout compartments and the evidence of new piping and steel maintaining their original appearance, are visual evidences of an effective system. Enough confidence has been created to warrant adoption of this program with the latest procedures on three new vessels presently under construction. This provides an ideal opportunity for application and analysis, and assuming that it is carried on successfully, actual results will be available within an 8-year period.

The author believes that a successful corrosion control program should be of interest to all connected with tankers. For the tanker owner, it can reduce maintenance and repair costs, and thus be a factor in enabling him to compete in the trade. It will help maintain the security of cargo segregation required for handling a variety of mixed products.

To the ship's personnel the minimum loss of ship's

original strength and the reduction of tank cleaning and tank maintenance work means a safer ship on which to sail and work.

Corrosion control should be beneficial to the shipbuilding industry, as it will assist owners to establish available funds for new construction and replacement tonnage.

All citizens and representatives of industry have an economic interest in effective corrosion control, for the ravages of corrosion on military vessels are reflected in taxation and on commercial vessels, their expense adds to the price of each gallon of petroleum product.

The author believes that the efforts and work recorded herein represent definite progress toward the solution of this vital problem.

Acknowledgments

Acknowledgment is made for the constructive comments on the preliminary drafts of this paper by Messrs. D. K. Laidlaw and G. D. Harden, of Shell Oil Company, and Mr. S. F. Spencer, of Keystone Shipping Co., and to Messrs. W. G. Neal and F. C. Braun, of Keystone Shipping Co., for their efforts in preparing the illustrations.

References

- G. D. Harden, Shell Oil Company, Products Pipe Line Department, "Mitigation of Corrosion Within Cargo Compartments Aboard A T-2 Tanker," dated November 1950.
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DISCUSSION

MR. WALTER L. GREEN, *Vice-President*: Part 3 is an important and interesting paper. Many valuable improvements in ship and particularly in machinery design were failures when first introduced, due to lack of interest and even positive opposition on the part of operating personnel. The author's point that co-operation must be obtained through the medium of making a job on the ship an easier and better task for the crew cannot be overstressed.

Does the author feel that any part of the improvement in corrosion rate is attributable merely to the discontinuance of the process of tank washing previously used?

From the naval architect's viewpoint the paper has great significance although it is evident from the facts presented that a body of experience must be built up over many years before much change can be safely made in scantlings.

Certainly when favorable results can be predicted definitely, several hundred tons of hull weight in many cases can be eliminated from the internal structure of a large tanker, as most prudent owners specify material in such parts considerably heavier than the scantlings required for strength considerations plus ordinary corrosion allowances.

Favorable results over a long period, particularly if external corrosion can be reduced simultaneously, might even lead to a review of present Classification Society requirements which now include some margins for corrosion.

MR. ROBERT W. MORRELL, *Member*, and MR. ROBERT C. MORRELL, *Associate Member*: Our comments are con-

finned to Part 1, Mr. Jupp's paper, and to the influence which the corrosion features presented therein may have upon the design of the hull structure of tankers. In particular, we wish to refer to the increase in hull scantlings over classification requirements, as a means of offsetting corrosion wastage.

This is a major problem in tanker design. Mr. Jupp's paper is the first and only presentation we have seen which offers a rational and scientific approach to that problem. The paper presents a rather new means of analysis by expressing wastage in terms of actual penetration rather than as a percentage of plate thickness. This line of thinking is very helpful in arriving at sensible scantling increases, and Mr. Jupp deserves real credit for his form of presentation.

We do not believe that hard and fast rules can be laid down for determining these increases. The classification societies have adopted in their Rules, in a very broad sense, a corrosion factor or margin of about 25 percent for major structural members. Many owners voluntarily have adopted increases over the Rules as a further margin against corrosion, but until now this has been rather haphazard.

We wish to point out that these owner's increases are as much a problem in economics as in engineering. The objectives are twofold: (a) to mitigate reasonably the cost of renewal of steel structure due to wastage, and (b) to prolong the useful life of the ship as a whole. The solution requires clean-cut understanding from the viewpoint of ship management as well as that of the naval architect.

In the design of any proposed tanker, such a joint decision as to the proper extent of scantling increases, and the best disposition of same, should take into consideration certain major factors. These we outline below:

(1) As to the grade of oil cargo and its characteristics, which the new tanker is intended to carry. The corrosive effect of the sour crudes is of considerable importance due to the number of vessels engaged in hauling Persian Gulf crude which is of high sulfur content. No group of tankers has been in this trade long or continuously enough to prove conclusively the extent of the corrosive effect of these cargoes. What data are available indicate that Persian Gulf crudes will parallel the effect of the continuous clean trade plus some pitting of the bottom shell as mentioned in the paper. Another angle is that tankers built for a special trade may later go into world-wide trade with almost any kind of cargo.

(2) The nature of the intended cargo will influence the reasonable expectation of useful life of a prospective tanker, and this must be taken into account in the economics of increased scantlings. On the second page of his paper, Mr. Jupp refers to 20-year life, half the time clean and half dirty, but his Figure 1 shows a 30-year scale for that combination and states it is equivalent to 20 years in clean service. We agree with the latter assumption.

There are two divergent lines of thinking regarding the expectation of the useful life of a tanker. One viewpoint is to adopt an arbitrary expectation of say, 20 years of life, to coincide with a bookkeeping setup

which writes the ship off in 20 years, based on a flat rate of annual depreciation of 5 percent. This would indicate the initial adoption of a small increase in thickness of selected members to provide the most economical combination to minimize or eliminate renewals over that period. At the end of 20 years, or at the second No. 2 special survey, the owner would then be faced with heavy expense for major renewals to prolong the vessel's life, or of scrapping. There is some merit in the ability to make such a decision at the time the conditions actually exist, rather than try to predict, at the time of design, what the market may be 20 years hence. The deferring of renewals by initial increases can be carried to the extent that they will occur beyond the otherwise useful life of the vessel and presumably never would be made.

The alternative approach to the useful life problem, in the design stage, would be to estimate the most economical combination of scantling increases and renewals to obtain the maximum life expectation for the given trade. Cost analyses can be set up to compare, on one hand the original cost of added steel, with the consequent loss of earnings over the life of the ship, against the considerable saving in eliminating expensive renewals.

(3) Consideration should be given to how much reliance is to be placed in any method or system of corrosion control, in conjunction with increased scantlings. The current systems are of such recent adoption that it may be unwise to assume that any of them can wholly eliminate corrosion or the need to increase scantlings to offset corrosion. Neither do we suggest eliminating all corrosion control and resorting wholly to thick plates.

Dealing with corrosion solely by adding margins of thickness to postpone renewals accepts corrosion as a necessary evil and does nothing to combat the basic cause. It can hardly be classed as a corrosion control. The adoption of dehumidifying equipment, anodic protection, an inhibitor, or other means of corrosion control, is essentially more logical in that it attacks the cause. It appears that the likely solution is the adoption of one or more of these control methods together with a very moderate increase in structural thickness. Considerably more experience with such combinations will be necessary in order to establish reliable quantitative results.

(4) The extent to which plate thickness should be increased should be considered likewise in conjunction with good structural hull design, to avoid hard spots and local overstressing which accelerates corrosion. Plate thickness should not be increased to offset corrosion which could be avoided by attention to design details.

We also believe that excessive or too frequent Butterworthing tends to promote corrosion and that scantlings should not be increased to provide against corrosion that could be avoided by efficient operational control.

(5) The loss of earnings due to decreased deadweight capacity, caused by increased scantlings, over a period of years up to the point of renewal of such members, must be considered carefully. In this calculation, it must be remembered that the longer the

renewals are deferred by reason of increased initial weight, the longer the period of such impaired earnings will be.

It has been contended that as wastage occurs the hull weight thereby is decreased, with corresponding gain in deadweight which partially offsets the loss just mentioned. On the other hand, so far as we know, the principle has never been accepted in marine transactions that a ship gains deadweight and consequent earning capacity during her lifetime by reason of wastage. Until such a principle is established, we consider our previous statement to hold, namely, that increase in scantlings represents loss of earnings.

(6) The first cost of any increase in scantlings, of course, must be taken into account. This would be relatively minor except in large tankers where the thickness of bottom shell, sheer strake and deck stringer come into the range of normalizing the steel. Any increase which brings the thickness into the normalizing requirement (about 1 $\frac{3}{8}$ -inch and above) represents the difference between normalizing and not normalizing, at an extra cost of about one dollar per pound applying to the total weight of the plates involved. Inasmuch as such plating (not normalized) can be renewed at about fifty cents per pound, it is apparent that increases in thickness which would introduce normalizing are not financially justifiable.

(7) In analyzing the possibilities of extended life, thought should be given as to whether it is desirable to increase the scantlings of certain members, in the original design, so that most of the cargo tank structure will require renewal all at one time. The data in Mr. Jupp's paper make it possible to calculate the thickness to approximate this condition. The alternative would be to design, by the same formula, so that the renewals would be staggered or spread over two or three special surveys. In deciding this question we must remember that any renewals of corroded hull steel will occur in the second half of the life of the tanker. If the renewals are postponed too long, the major expense for same would occur near the end of the vessel's useful life and the ship would eventually be scrapped, for reasons other than the recently corrected corrosion, with a lot of new plating which has given a poor return on a very heavy investment.

(8) In deciding on the desirable increase in scantlings for new design, the answer must lie between two extremes of no increase at all over the Rules on one hand, versus major increases which would insure no renewals being required during the life of the ship, on the other hand. The former would require piecemeal renewals at the first No. 3 special survey and at each special survey thereafter. The latter would produce such a heavy ship and impairment of deadweight as to be prohibitive. The solution lies in a middle course, arrived at by a careful application of the very useful data embodied in Mr. Jupp's paper, accompanied by the exercise of good judgment.

(9) The final decision as to increases involves a balance between first cost and loss of earnings on one hand versus premature cost of renewals on the other. The latter, in our opinion, is a feature which has been overstressed. In considering the possibility of prolonged life, since most of the tank structure

has to be renewed at one time or another during the life of the ship, unless saved by one or another of the corrosion control projects now under discussion, it makes little difference whether a given renewal occurs at the age of 16 years or 20 years. It appears to us that such deferment only involves interest for four years on the cost of the renewals in question.

(10) Where possible, we are in favor of allocating certain cargo tanks for ballast on ballast voyages, and putting no ballast in the other cargo tanks except in emergency or for tank-testing. The alternating of cargo and ballast in a tank accelerates the corrosion; and the elimination of ballast from as many tanks as possible will minimize the cost of steel renewals in those tanks.

For a tanker in a fixed trade carrying cargoes of such gravity that part of the cargo tank cubic capacity is not utilized, we advocate, if possible, allocating certain cargo tanks to be carried empty on the loaded voyages; always the same tanks. This likewise minimizes the corrosion and cost of steel renewals in the latter group of tanks.

Naturally, the selection of such tanks, whether for regular ballast tanks or as empty spaces when the ship is loaded, must be the result of careful analysis of loading diagrams, to arrive at the minimum bending moment and stress for both conditions. Adherence to these conditions should not be mandatory on the Master; he must be free to exercise judgment to suit circumstances on the spot, but the suggested procedure could constitute a valuable guide.

Adoption of such a program may result in designing the cargo tanks in four groups for a given trade: (a) cargo and ballast alternating; (b) cargo only; (c) ballast only; (d) completely void. In all but (a), the rate of corrosion would be definitely reduced, the cost of steel renewals limited accordingly and the need for increased scantlings almost eliminated.

Reference was made above to empty cargo tanks on a loaded voyage in a fixed trade. It might appear that the cargo space should be designed to suit the intended cargo, without such surplus space. There are two reasons why not. A normal ratio of cargo cubic should be maintained, regardless of the intended trade, first to maintain proper distribution of the cargo rather than concentration of load and second, because no one can say that the ship will never be required to carry a light gravity cargo requiring full cubic capacity.

(11) A highly desirable precaution in new tanker design is to have the drawings of the Midship Section, Shell Expansion, Oil Tight Bulkheads, and Upper Deck Plating show for each member the Rule thickness and the owner's increase in thickness separately. Then when the plating is drilled or Audigaged at some subsequent special survey, the necessity of renewal would be determined by the wastage applied as a percent of the Rule thickness, not of the total original thickness. Also, the renewal would be to Rule thickness, not the original total, unless the expected life of the ship indicates that the renewal might have to be repeated in later years.

We have taken the midship section of a typical recent supertanker and have applied the penetrations from Mr. Jupp's curves to the basic Rule scantlings, omitting any owners' increases over the Rules intended to offset corrosion. This investigation shows that at the third No. 1 survey, after 12 years of half clean, half dirty service, 97 tons of steel would require renewal due to wastage beyond an arbitrary 25 percent limit. However, if in the original design the thicknesses of these members were increased slightly, involving 14 tons added initial weight of hull, these renewals could be postponed at least to the 16-year survey.

After 16 years in half clean and half dirty service, this same ship having bare Rule scantlings would require steel renewals amounting to 695 tons. Similarly, if the thickness of these corroded members had been increased in the original design, involving 90 tons added weight, these renewals could be postponed until the 20-year survey.

These figures show some economic justification for moderate increase in the designed thickness of the members affected, based on a useful life of vessel up to 20 years. It also appears that such increases will result in considerably less net expenditure than the \$1,000,000 cost of renewals mentioned in the paper. Some cautions must be used in applying these data, however, since the paper specifically states that its figures are averages and it is feared that too many variables may be included in such averages. In designing for a particular trade it is difficult to apply a correction because the bases of the averages are quite indeterminate.

In conclusion, we wish to recommend in tanker design, a careful study of the possibilities of a good combination of moderate scantling increases over Rules with some corrosion control system and special allocation of cargo tanks for ballast. Such a study is necessarily complicated, and we are indebted to Mr. Jupp in pointing out an intelligent approach to the application of corrosion margins for hull scantlings.

MR. OLIVER D. COLVIN, Member: The three parts of this Symposium show thoughtful, energetic preparation by the authors. The conclusions as to the advantages and the limitations of the various systems are very fair and afford bases of comparison for operators who have special problems in their own fleets. Congratulations for a practical paper.

It seems clear from the paper that no single system can prevent corrosion at all times. As Mr. Jupp points out, much can be done in design by eliminating "hard points," though general corrosion still must be attacked. Coatings, including metallic sprays, are excellent as long as the coverage is complete and remains intact. The cost to apply and maintain these coatings, including lay time, is of concern to the owner. As pointed out in Parts 2 and 3, inhibitors and anodes seem to have a place in the picture but cannot be effective all the time, such as when the tanks are empty. Dehumidification (D/H) is most successful in the cases where the other methods cannot be of use, but D/H in turn cannot be of much help in a tank of ballast. It does, however, prevent

adjacent tanks from sweating, which is an aggravated condition for corrosion as an abundance of oxygen is present and the electrolyte is strong. Mr. Jupp also notes that "ballasted tanks have no higher corrosion rate than tanks normally empty on the ballast run."

It is indicated that tankers should be protected by a combination of one of the above systems with dehumidification. In cold weather a man likes a shirt as well as a pair of trousers to keep him warm. In "mothballing" the laid up ships of the U. S. Navy, a process initiated by our staff, D/H was complemented by use of polar compounds on certain machinery to hold off corrosion while the ship was being laid up or recommissioned. Dehumidification "protects the protection" and would minimize the cost of anodes or coatings. It seems clear that a similar combination of methods might be the practical answer when all the costs are considered. These would include initial installation, renewal of installation, costs of maintenance, loss of use of ship during renewal and gas-freeing periods and labor costs including crew overtime which is far from insignificant.

The largest single savings would be in the elimination of large replacements in the ship's structure during its normal life. The papers indicate that if a ship can stay in "clean cargoes" throughout its normal life of 16 to 20 years without replacement of bulkheads and main structures, savings of over \$1,000,000 can be effected. These costs do not include losses in lay-time, gas-freeing time, crew overtime and maintenance on pipes, pumps nor savings in delivering cleaner cargoes. An overhaul can take three months. A total investment of \$75,000 for D/H completely installed looks like a good proposition if this saving can be approached.

Mr. Malcolmson and his colleagues mention in Part 2 the cost of operation and maintenance of D/H equipment. The owner of a Dutch tanker fleet examined his records of 25 years of experience. His conclusion is that with all operating costs and maintenance costs added to the total cost of installation, the system would pay for itself by the extension of the life of the ship of only one year. He is now installing D/H in two ships building in Holland.

Mr. Jupp mentions frequently that scale itself promotes corrosion (a) by breaking up, which allows corrosion to speed up; (b) by holding moisture (wet electrolyte) in contact with the ship's structure; and (c) by accumulating on flat surfaces, retaining strong brine in contact with the underlying steel.

Experience in two completely equipped American tankers, aged 5 and 10 years respectively at time of installation, shows that D/H properly installed and operated causes scale to fall off of its own accord in a matter of weeks. It does not return even though Butterworthing is frequent; i.e., Butterworthing need not be abandoned. Automatic controls and recorders save time of the busy deck crews. The recorder gives not only a voyage record for the owner but is of continuous service to the ship's officers in understanding and maintaining corrosion control.

Mr. Kurz, in Part 3, reports great progress in chemical inhibition reaching at the present stages of development to all but 5 to 10 percent of the surfaces

in non-ballasted tanks which, as stated, is not enough coverage to prevent renewals of structure. It would seem probable that in time the amount of specially trained personnel and crew time would be reduced. The human element is not always reliable in fast operating tankers, especially in adverse weather conditions. Perhaps automatic controls and recorders could be developed to give better knowledge of what actually was done to the tanks. A reduction of 80 percent in corrosion in non-ballasted tanks is a great achievement.

Again congratulations to the authors for a good paper written by practical operators of the ships where theory and science must prove itself under conditions not encountered in the laboratory.

MR. H. J. DEAN, *Visitor*:* The author is to be congratulated on preparing a concise survey of the extent and types of corrosion experienced in oil tankers and of the various methods which are being employed for combating corrosion.

This survey in Part 1 appears, however, to be limited to the trade of which the author has the greatest practical knowledge, i.e., Mexican Gulf/North of Hatteras. British and Continental tanker operators have in the main to contend with voyages of considerably longer duration, e.g., Persian Gulf/U. K., Continent and consider themselves fortunate if they can complete ten voyages a year against the twenty-five voyages a year quoted in the author's paper. They, therefore, have cargo and ballast in the ship for much longer consecutive periods and different conditions are created which may affect the rate of corrosion and also the efficiency of methods of combating corrosion. There are, at present, ten British and Continental tankers being fitted out with the dehumidified atmosphere process mentioned in the author's paper.

In view of the much longer voyages to which these vessels are committed, the efficiency of a dehumidified atmosphere is greatly enhanced as the number of days per year employed in cleaning and drying the tanks is smaller and the number of days per year during which the tanks are completely dry is greater than would be experienced on shorter voyages.

The empty and cleaned conditions are of increasing importance to the European operator as the whole pattern of the oil trade has changed since the war. For economic and political reasons, instead of carrying refined products to European ports, the majority of tanker tonnage is now employed carrying Middle East crudes to European refineries. This has brought new corrosion problems as corrosion has been found to be much more intense on bottom plating and horizontal stiffeners during ballast voyages than was ever experienced with refined oils.

Tables I and II indicate that corrosion is at its greatest rate during empty and cleaned conditions (particularly with sour crudes) and also that moisture elimination is most efficient in combating corrosion under these conditions. If we can assume that tanks can be kept dry with dehumidified air for say

130 days a year on long voyages, and that corrosion is normally greater during this period than during the loaded period, then it can also be assumed that dehumidified air should reduce the corrosion rate by about 50 percent.

As far as the cost of this process is concerned, it was recently estimated by a leading European tanker owner that the cost of fitting and operating a dehumidified air system was the equivalent of one year's extra life of the ship. In other words, if corrosion were sufficiently retarded to increase the life of the tanker by one year, then the system would have paid for itself.

MR. S. J. DULY, *Visitor*:* Part 1 is an interesting survey of the progress of corrosion in the cargo-carrying spaces of tankers engaged in the trade between Venezuela, Aruba and the East Coast of America. In it the author shows that the rate of corrosion is approximately proportional to the time the ship has been in service and gives figures indicating its enormous extent.

In his opening paragraph, the author points out that vessels operating exclusively in fresh water, as on the Great Lakes, show low rates of corrosion in comparison. This is presumptive evidence that the rate of corrosion is dependent on the use of salt water in cleaning and ballasting ocean-going tankers. In fact, if the cargoes are similar in composition, it would follow that the principal cause of the higher corrosion rates experienced in tankers in this trade is due to the use of sea water for these essential purposes. To reduce this rate, some controls of the corrosive effect of salt water is needed. It appears from Table I that in this trade corrosion is most active when the tanks are cleaned and empty. During these times the use of dry air must be of very great advantage in reducing corrosion.

Experimental work by the writer, carried out in 1950,** shows that sea salt exposed to a dry atmosphere loses moisture until it contains about 9 percent of water by the time it reaches equilibrium with air 50 percent saturated. The salt is then still in a sample state as shown in Figure 41, but in this state it is dry enough to be relatively innocuous.

In an atmosphere 50 percent saturated, the corrosion of bright steel by sea salt in contact with it is very remarkably reduced. For instance the weight of steel corroded away in a fortnight by sea salt in equilibrium with air of 50 percent relative humidity is only about 12 percent of the weight corroded away in an atmosphere at 80 percent relative humidity when the temperature remains at 75 degrees F. (See Figure 42.) There is very good reason therefore to anticipate a great reduction in corrosion in tankers in this trade by the use of dry air.

MR. JOHN F. ROESKE, *Member*: That the tanker corrosion problem has been earnestly attacked with considerable success is evident from Part 3 of this symposium. Experiences on the scale of 12 inches to the

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* Director, Cargocaire, Ltd., London, England.

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Foot are bound to give results that can be relied upon and the Keystone Company is to be commended for their courage and carefully planned operations. In the whole problem of tank corrosion, the larger part by far is in taking care of existing construction where it is almost impossible to do anything. With present material, poor accessibility such as the underside, of flanges, brackets, longitudinal stiffeners and piping, there is difficulty in completely spraying all parts, as is noted in the paper. In view of this, the writer has thought that in new construction, the replacement of the angle and Joder shapes with bulb plates and angles wherever possible would present less hard-to-get-at surfaces. Unfortunately these sections are practically impossible to obtain but I think the suggestion merits consideration.

The successful use of any inhibitor obviously is dependent on clean surfaces. In examining the sketches, the large number of anodes is quite striking. Has it been possible on the basis of the author's experience, to arrive at a definite conclusion as to how much anodic surface is required for a given tank volume and surface? It is noted that a reduction of 50 percent or better has been obtained and does there appear to be a limit irrespective of the amount of anodic surface?

In the center tank of a T2 tanker the exposed steel surface is about 16,000 sq. ft. and the surface of 74 anodes is about 266 sq. ft. This is a ratio of about 60 to 1, which seems small. The anodes contain quite an amount of zinc and aluminum, is this intentional for a commercially available grade? Has the author tried a different grade in order to note the effects? Likewise what is the distribution of the anodes in relation to the severity of corrosion in different parts of the tank, as for instance the deck and upper strakes of the bulkheads? Obviously, many arrangements are possible and it doubtless will take much time before a final conclusion can be stated. A reduction of 50 percent is indeed good but doubtless much better results possible. A really satisfactory result will be achieved only when a material less susceptible to corrosion is available. No owner or shipbuilder can be happy when he sees the toll that corrosion takes in the present tanker and the necessity of developing a steel possessing better anti-corrosion properties, together with satisfactory weldability, is necessary if for no other reason than to avoid the setup of machinery, special operating personnel and layup for renewals.

MR. WILL COOPER, *Affiliate*: These three papers are most timely, apt and concise but give a very comprehensive coverage of this complex subject. I can find little to differ on with the several authors. The

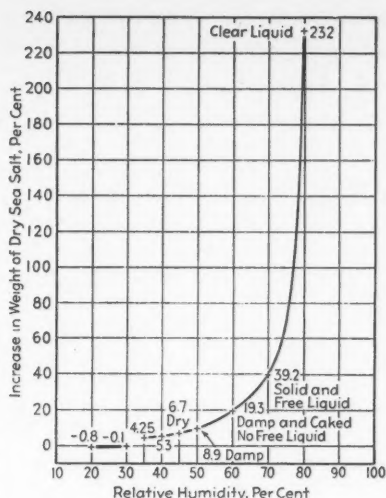


Figure 41

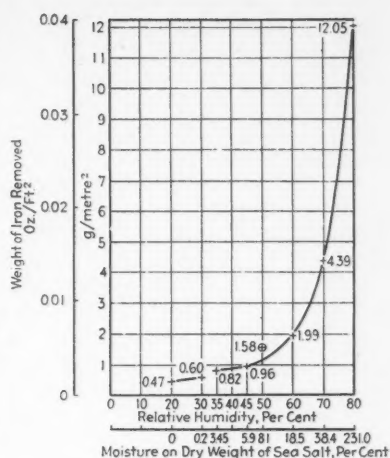


Figure 42

material is factual and therefore does not furnish much which could be a basis for controversy although there is abundant opening of suggestion and additional information on the various aspects of this subject, by those who are qualified by experience to help. It is my intention, therefore, in this discussion to handle only one phase of this corrosion problem—one that I am slightly qualified to speak on—and that is the prevention of corrosion by the elimination of oxygen from the atmosphere in the tanks. As Mr. Jupp's paper is the only one which touches upon this method my discussion must necessarily be confined to his paper alone and I will try to furnish some additional information which Mr. Jupp says he does not have and which may be of value to the industry.

Mr. Jupp says in one place, "There are considerable data indicating that moisture with a low pH value and high oxygen content will produce the most rapid corrosion," and then in another place he says, "The corrosion taking place in tanker operation is dependent mainly upon water and oxygen in contact with the steel," and then he draws the conclusion, which is quite logical, that this being true the methods best adapted to control corrosion when oxygen and moisture are present is to keep these two agents from coming in contact with the steel. There are several ways of doing this and he elucidates by explaining each method with more or less detail. One of the methods is to eliminate both the oxygen and the moisture. It is impossible to eliminate the moisture while the vessel is in ballast, which is the time when most of the damage is done, but it is possible to eliminate the oxygen. He says that this has been tried by the introduction of flue gas into the tanks but that "the tests which have been carried out have been primarily under the supervision of one company" so that he does not have any information about this method. It is information about the characteristics of flue gas with which I had some experience, that I propose to furnish in this discussion.

Flue gas itself will never be practical for inhibiting against corrosion on shipboard because, as Mr. Jupp

points out, it requires too much cumbersome equipment to condition it. But there is still another and a more serious reason which he has not mentioned, for even after it has been washed and conditioned it is still not of a proper composition for satisfactory handling. The theory of flue gas is that the atmosphere may be rendered inert and oxygen-free by burning the oxygen out of it and replacing it with compounds of oxygen and the combustibles such as CO_2 , SO_2 and H_2O . But this is true in theory only. The complete elimination of all of the free oxygen comprehends perfect combustion which is very hard to accomplish even in a laboratory and is never attained in practical operation on shipboard or any other place. Flue gas, therefore, always contains some free oxygen and the disadvantages of free oxygen in a corrosion inhibitor are too evident to need comment. This is objection number one. For the sake of this discussion, however, we will assume that there has been perfect combustion; that all of the free oxygen has been combined and that there is none remaining in the flue gas when it enters the tank. What sort of a mixture is it and what are its characteristics?

The atmosphere which is the basis for flue gas is roughly 76 percent nitrogen, 21 percent oxygen and the balance small quantities of carbon dioxide and argon which are not large enough to be factors in this discussion. Anyway they are an aid to the inhibiting. As the nitrogen is unaffected by the reaction of combustion it is found unchanged in the flue gas and (while it is as good an inhibitor as the products of combustion) its presence in such a large proportion gives a resulting product which is so near the same specific gravity as the atmosphere that it readily diffuses and will not "stay put." The consequence is that the operator is faced with the necessity of keeping up a constant injection of it to the tanks to maintain the required conditions. Moreover, as it will not seek the lowest levels there is never any assurance that all parts of the tanks are filled with it. This is objection number two and it is the big one.

Mr. Jupp has called attention to the probable high dew point of flue gas due to its having gone through the washing process, but he has not mentioned the fact that it has inherent moisture as one of the products of combustion even if it had never gone through the washer. If the elimination of all oxygen is an all-around practical method of inhibiting corrosion, carbon dioxide is the ideal medium with which to do it. Not only is it inert as far as its use with petroleum products is concerned, but commercial carbon dioxide is absolutely dry and has considerable affinity for water so that it would pick up any moisture which might be in the tanks where it was put. It can be stored in such manner that a vessel could carry several tons of it without too much inconvenience, enough to last for an entire voyage and the supply can be replenished in almost any port. The principal objection to its use is its cost which is too high but increased use would bring the cost down because it basically a very cheap commodity and is a wasted by-product in many industries. Furthermore with some urging on the part of marine operators considerable improvement in the present

methods of storing it could be made which would lessen the weight and space requirements and should make it even more attractive than it is now.

MR. F. L. LAQUE, *Affiliate*, and MR. THOMAS P. MAY, *Visitor*:* The three papers in this symposium provide a valuable contribution to our knowledge of this important subject. The first paper by Mr. Jupp is of special interest to all of us who have been carrying out corrosion tests in this field because it provides quantitative data on the rates and distribution of deterioration determined by measurements of actual metal losses in tankers operating in different services over long periods. This gives us a yard stick for appraising the reliability of results of tests on relatively small unstressed specimens installed in operating tankers. The information he has provided on the economic factors is also very helpful in indicating how much we can afford to spend on remedial measures.

With the cooperation of the operators, we have exposed corrosion test specimens in 10 tankers operating in both clean and dirty service with and without sea water or brackish water ballast. The results of these tests have been summarized in Table XIV.

Outside of the localized accelerated corrosion associated with cyclic stresses as described in Figure 3 of Mr. Jupp's paper, the rates of corrosion shown by the test specimens checked very well against the average rates observed in practice as illustrated by Figures 1 and 2 of Mr. Jupp's paper. This gives us enough confidence to attempt to provide answers to some of the nine questions listed by Mr. Jupp as follows:

(1) What percentage of the over-all corrosion occurs under the various conditions of cargo-ballast-clean, etc.?

(a) Corrosion by a salt atmosphere will average about twice that of steel immersed in sea water.

TABLE XIV—Average Corrosion Rates of Steel in Operating Tankers
(From Small Specimens in 10 Tests of 1 to 4 Years)

Exposure Conditions	Corrosion Rates in Inch per Year			
	Top of Tank		Bottom of Tank	
	Average	Max.	Average	Max.
Clean sea water.....	0.006			
Sea atmosphere.....	0.010			
Gasoline, no ballast.....	0.011	0.014	0.010	0.011
Gasoline, sea water ballast.....	0.009	0.012	0.006	0.007
Gasoline, brackish water ballast.....	0.011	0.012	0.003	0.003
Crude oil, brackish water ballast.....	0.004	0.004	0.001	0.001

TABLE XV—Corrosion Rates of Steel by Different Sprays

Solution Sprayed	Inches Penetration per Year in 300 Hr. Test
Distilled water.....	0.014
3 percent sodium chloride.....	0.006
20 percent sodium chloride.....	0.001
Natural sea water.....	0.008

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- (b) Corrosion by clean cargo (gasoline) will be about the same as that by a salt atmosphere and will be about the same in vapor spaces in clean service whether or not ballast is used on return trips—while the use of ballast will reduce corrosion of submerged surfaces by about 50 percent.
- (c) Corrosion by dirty cargo (crude oil) will be about one-third that by clean cargo in both vapor and submerged spaces. (This supports Mr. Jupp's assumption that one year in clean service is equivalent to three years in dirty service).
- (d) Corrosion in vapor spaces is from 50 percent to 75 percent greater than that of submerged surfaces when ballast is used in clean service and four times in the less corrosive dirty service. This latter does not include rapid pitting sometimes observed in tank bottoms in dirty service which will be discussed in more detail later.
- (2) What is the difference in corrosion between the plate not under strain or not working and that of one subject to high strains or flexing under load?

We believe that stresses below the elastic limit will have a negligible direct effect on the rate of corrosion of steel in these environments. However, stresses, and particularly cyclic ones, which will cause spalling of rust films so as to expose fresh surfaces to corrosion at relatively high initial rates can and do cause accelerated attack (as compared with corrosion rates observed over a long period, e.g. in a year, about 0.006 ipy) in sea water, the rates during the early stages of corrosion will be much higher (e.g. 0.017 ipy). This must be taken into account in applying data from unstressed test pieces, as well as in modifying structural design so as to minimize stresses that would permit the high rates of early corrosion to persist.

- (3) Does the rough surface of an already corroded plate increase its rate because of the increase in surface, or is the increasing rate of corrosion due to its greater unit stress?

Roughening of a surface by corrosion would be expected to increase the extent of weight loss by presenting a larger area over which corrosion will occur. However, the depth of attack will not be increased in proportion since the action will result in lowering the tops of the hills and cutting into their sides, as well as deepening the valleys. Consequently, the average depth of attack is not likely to be increased significantly by the roughening effect of corrosion. As indicated in the discussion of Question (2), the effect of corrosion on unit stresses and vice versa is not likely to be serious until the section has been weakened sufficiently so that enough cyclic deflection to spall off protective rust films is permitted.

- (4) Does the breaking away of scale at the points of flexure in itself affect the rate of corrosion?

If the scale referred to here is rust scale, the answer has been given already in discussing Questions (2) and (3). If mill scale is meant, any local spalling of this scale by stress effect can promote accelerated corrosion of such surfaces when submerged in salt water. Steel carrying mill scale is at least a tenth of a volt more noble than bare steel and the relatively larger area of this more noble scaled cathode can support a vigorous galvanic corrosion of the metal from which the scale has spalled.^{3, 2}

- (5) What percentage of the corrosion occurs on the side of the plate carrying ballast and in the empty tank due to sweating from differences of temperature of the ballast and the empty tanks?

Our estimate is that corrosion of the empty side will account for from two-thirds to three-fourths of the total corrosion under these circumstances with the lower fraction applying to the upper portions of the structures.

- (6) Would the removal of scale reduce or accelerate the general corrosion?

We believe that the complete removal of rust scale so as to expose a fresh metal surface will accelerate corrosion. If the heavy scale that can serve as a reservoir for corrosive liquids can be removed without disturbing the thin protective layer right next to the steel, corrosion can be reduced by such partial scale removal.

- (7) What effect would an occasional fresh water wash of the rusted bulkheads have on removing brine and how would this affect the corrosion rate?

Aerated fresh water is surprisingly corrosive as compared with salt solutions or sea water. Alternate immersion tests in distilled water and sodium chloride solutions carried out by Portevin and Herzog³ showed that distilled water can corrode steel faster than brines stronger than about 6 percent concentration (due probably to the lower solubility of oxygen in the strong brines). Conventional salt spray tests on bare steel at about 95 degrees F gave the results in Table XV.

From these observations, it would appear that replacing salt water with fresh water spray would have only a moderate effect in reducing corrosion. The greatest benefit might come from the removal of hygroscopic salt particles which permit corrosion to continue at a lower relative humidity. This effect might not be noticed where the relative humidity is regularly high or where the surfaces are frequently wet with condensate.

- (8) What is the chemical analysis of the water retained in heavy scale under varying operating conditions?

We have no information on this question.

- (9) What is the corrosion rate of steel in a hot salt saturated atmosphere in comparison to a steam saturated atmosphere?

A partial answer to this has been provided by the results of the salt spray tests referred to with respect to Question (7).

Specimens of steel exposed over a vessel in which salt was being crystallized from a boiling saturated solution showed a rate of corrosion of only 0.001 ipy. Similar rates have been observed on specimens suspended in the vapors of sea water distilling units.

Corrosion of steel by oxygen-free steam is negligible—by air saturated steam condensate, it has been observed to be as high as 0.24 ipy.⁴ The difference here is due probably to the extent of condensation on the specimens rather than to any protective effect of something released from the boiling brine.

In addition to these attempts to answer Mr. Jupp's specific questions, we offer the following comments on a few other points:

(A) Specimens of low-alloy, high-strength steels included in the tanker corrosion test program showed improvements in corrosion resistance as great as 3 to 1 in clean (gasoline) service. The 25 percent improvement in life anticipated by Mr. Jupp from the use of these special steels can be considered as a conservative estimate—especially with respect to the vapor spaces where the corrosive effects are greatest.

(B) Specimens of steel were exposed to sea water for 150 days under three conditions:

- (a) Immersed in clean sea water in an inlet where the tidal velocity was about 2 fps. Under these conditions, the rate of corrosion was 0.008 ipy.
- (b) Immersed in clean sea water lying quietly in an open vessel. Under these conditions the rate of corrosion was 0.002 ipy.
- (c) Immersed in sea water lying quietly in an open vessel, but with the sea water adjusted to a pH of 10.5 by the addition of caustic soda (4 oz. per cu. ft. of sea water). Under these conditions the rate of corrosion was 0.0002 ipy.

It is evident from these and similar supporting data that corrosion of steel by relatively quiet sea water can be reduced almost to zero by making the sea water more alkaline (pH 10.5 or so).

(C) In considering the use of sprayed zinc to avoid accelerated corrosion of areas subjected to cyclic stresses it must be remembered that when the tanks are ballasted with salt water the relatively small patches of sprayed zinc will be acting as anodes in galvanic cells in which the area of the surrounding bare steel cathodes will be very large. This could lead to rapid corrosion and short life of the sprayed zinc.

(D) Cathodic protection by current from magnesium anodes or other sources can be expected to prevent corrosion of accessible surfaces submerged in salt water. This device, of course, will have no effect on surfaces exposed only to vapors and the salt atmosphere and something else will be required for protection in these areas. There also may be problems in the location of anodes so that sufficient current for protection will flow to corners and recesses.

The calcareous coatings formed during cathodic protection in sea water have some protective value upon subsequent exposure to a salt atmosphere⁵ for a short time, but lose this effect upon prolonged exposure without periodic application of current. The corrosion of magnesium anodes to generate protective current is accompanied by the evolution of hydrogen which can form an explosive mixture in the atmosphere in a tank. While operators are accustomed to coping with the hazards of explosive vapors, it is necessary to be aware of the possible danger from this source.

(E) In view of the drastic effect of cyclic stresses in accelerating corrosion in local areas, the results of tests on unstressed specimens do not apply to surfaces subjected to such cyclic stresses. Thus, tests on unstressed specimens will not establish the ability of inhibitors in the cargo to take care of corrosion in areas where protective films may be spalled off by cyclic stresses. Actual experience will be required to settle this point.

(F) Unusually deep pitting has been observed on steel, as in tank bottoms in contact with crude oil carrying some salt water in suspension. Drops of water on steel surfaces can cause deeper corrosion than if the surfaces were completely covered with salt water because each drop favors the development of a differential aeration corrosion cell in which the anode is located near the center of the drop and the cathode around the periphery where the availability of dissolved oxygen is greater. Similar localized dif-

ferences in oxygen concentration are not so frequently encountered on completely flooded surfaces.

(G) In view of the complexity of the over-all corrosion problem, it seems likely that the best results are likely to be secured by the appropriate application of several remedial measures rather than by depending on any single step to overcome all the difficulties.

In conclusion, we congratulate the authors of the papers in this symposium for providing such an excellent practical basis for a further attack on the serious problem of deterioration of tankers.

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CAPTAIN CARL J. LAMB, USNR, Member, and MR. C. R. LOWE, Visitor.* The authors of Parts 1 and 2 of the Symposium on Control of Internal Corrosion of Tankers are to be congratulated upon the extremely interesting constructive and valuable papers which they have presented. The nature of the data presented would indicate a thorough approach to the problem of controlling internal corrosion of tankers, a thorough understanding of the causes, and a suggested method of an appreciable extension of life from 2½ to 4 years.

From our observations in the inspection of the internal spaces of MSTs tankers, both Government-owned and chartered, the question of designing to reduce or eliminate the points of maximum working (or hard points), in the general structure seems to be one that is extremely important and that offers real possibility of reducing extensive corrosion and failure of bulkheads at these particular points.

All of the authors have recognized the possibility of electrochemical corrosion (galvanic action) being an important factor in the excessive internal corrosion of tankers. Based upon data used by some of the commercial shipyards, the normal and inherent rate of electrochemical corrosion of unstressed steel at 75 degrees F in sea water appears to be approximately 0.015 ipy, if no other metals be present. It should be noted here that electrochemical corrosion of a single base metal, in this case ferrous, will depend upon several factors in the metal. Ions normally will travel from hard spots to softer spots, from rough surfaces to smooth surfaces, from parent metal to non-ferrous segregations and from stressed to unstressed areas, exactly as though they were traveling from one metal to another metal. In order to reduce

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or eliminate marked and excessive corrosion at local hard points, it is apparent therefore, that a primary step in the right direction is to eliminate the hard point if possible. It should be remembered, however, that in the case of a single metal immersed in an electrolyte, the positive ions from that metal can enter the solution only when an equal of positive ions of some other element are displaced in some manner, in the specific case of steel in contact with an electrolyte, the element which is displaced is hydrogen which gathers on the surface of the steel as a thin, protective layer and when this film of hydrogen has formed it insulates or prevents the further progress of the corrosion action. However, this hydrogen film easily may become removed either by joining oxygen in solution in the electrolyte, or by displacement due to motion of the electrolyte, resulting from flow, agitation, etc.

When the hard points were metallically sprayed with zinc, the ion flow would be from zinc to steel. It is noted that sufficient zinc oxide was formed in such a case as possibly to degrade the quality of gasoline or clean oil being carried. It is also of interest, that since steel is more electropositive than lead in galvanic series, there is a very distinct possibility that some of the excessive internal corrosion of tankers carrying high-octane-rating gasoline may be due to ion flow from steel to lead.

Since magnesia is the most active of the commonly used elements in the galvanic scale, the possibility is suggested of placing magnesium angles, for example, by welded steel clips and wedges held, along the vertical and horizontal boundary angles of all tanks, and possibly in nearest possible proximity to all hard spots. This is suggested due to the greater efficiency and consequent more rapid flow of the magnesium ions, the greatly reduced weight of magnesium as compared with zinc for the same surface area and volume and a possibility that the magnesium oxide film might not degrade high octane rating avgas to the extent found with the zinc oxide.

Of equal importance is the use of inhibitors in cargo which appears to offer promise. In this connection, we have observed that one of the major oil companies has reduced appreciably the cleaning period of pipe-line systems handling clean oils from approximately a two-month period to approximately an eighteen-month period by the use of inhibitors. This same company which uses such inhibitors in all light oils believes that tank cleaning and maintenance operations, both ashore and afloat, will be appreciably reduced due to inhibitors.

While a copy of the paper on "Corrosion Control in Practice" by Mr. A. B. Kurz has not been available to us, we have had the opportunity in conjunction with the Industrial Manager of the Eighth Naval District, of observing certain tanks aboard the S. S. *Cherry Valley*, equipped with cathodic protection in the form of suspended cylindrical magnesium anodes and also of certain tanks equipped with a chemical inhibitor spray system. The tanks fitted with the cathodes were found to be unusually free of rust scale, either on the plates or in the form of loose scale on the bottoms. Those areas of the tanks equipped with

the chemical spray system which were noted to be free of scale appeared to be unusually free of rust, indicating that the chemical spray wash had retarded the formation of new rust, but the results did not appear to be as effective as in the tanks fitted with the magnesium cathodic protection.

In conclusion, we agree in the main with Mr. Jupp's cost analysis on page 001, and that probably the greatest possible reduction of internal corrosion of tankers, and consequent increases in the useful operating life of the tankers, will be obtained by correction of hard points, a more widespread use of cathodic protection anodes, probably of magnesium and a widespread use of corrosion inhibiting methods.

It is worthy of note here that one operating company carrying, principally, avgas in certain clean tankers, is using a CO₂ blanket both when carrying cargo, in ballasted condition and empty tanks on return voyages and when loading. We have not been informed whether the main purpose of the CO₂ blanket is primarily to reduce fire and explosive hazards alone, or whether the operators hoped that the use of an inert gas in tanks at all times might reduce corrosion.

MR. C. HASTIE, *Member*: The presentation in Part I of pertinent correlated information will be invaluable to the shipowner and his executive staff of technicians and is deserving of the highest appreciation from those members to which it applies. Such data are anything but easy of acquirement and the admirable compilations by the author should invoke in discussion experience from those engaged in the operation of tank vessels carrying petroleum in bulk.

With reference to Figure 1 it is rather disquieting to learn that the over-all average regarding corrosion impedimenta is approximately the same for the more modern tankers as it is for those of the earlier carriers of summer-tank type.

The observations for cost comparisons covering specific numbers of voyages from a ratiocinative basis of crude oil carriers and those conveying gasoline or kerosene cargoes as clean traders is worthy of particular note.

With the refined oil carriers, unfortunately it has always been the gasified vapor purling against the deck heads and upper internal structures of the tanks that has effected the most rapid deterioration.

Does the author have any direct information between the conventional riveted vessel and the all-welded vessel, both as to like age, like cargo and like voyaging conditions for a comparison as to easier cleaning process of the one as against the other?

From the standpoint of "moisture held in suspension," as the author points out, this is evidently the prime cause of the deleterious effect of having to utilize salt sea water.

With reference to hard spots in design, the seriousness of the situations will be increased under rapid alternative ballasting conditions.

The sketches in Figure 3 are interesting and offer food for thought. It might be worthwhile respecting the corrosive condition as depicted at transverse bulkhead, Sketch C, if the disposition of the mount-

ing bracket to bottom shell longitudinals was off lighter scantling and that the adjacent ends of the longitudinals were diagonally snipped, for the corroded area of the bulkhead immediately above the bracket is precipitated through stress-rigidity of assembly. It might help too in respect to the horizontal bulkhead stiffener in Sketch A, if same instead of being fitted parallel could be set at a suitable declining angle accomplished by beveling from the lower faying edge of contact.

Regarding the stressed fluted bulkhead panel, Sketch B, probably this condition conceivably may be helped or counteracted by a lapped connection rather than a butt connection of the sections or the fitting of vertical single plate stiffeners in the bays staggered across the bulkhead at strategic area levels.

It will be interesting to learn in due course as to the outcome of the various inhibiting corrosion tests which are described, together with mode of application by the authors in their contribution of Part 2.

The authors are deserving of a vote of special thanks for their contributions respecting this intensely important matter affecting the structures of oil-tanker carrying vessels.

MR. HERBERT F. PARKER, *Associate Member*: The shipping and shipbuilding industries are greatly indebted to the authors of all three papers for their valuable analyses of the subject of tanker corrosion. A vast effort must be directed toward seeking economical methods of solving the corrosion problems encountered in various phases of operation.

The possibilities of chemical inhibitors, special protective coatings and cathodic protection must be examined exhaustively, but as yet none of these methods has been established as being economical, simple to apply, sufficiently effective and reliable under sea-going conditions.

Mr. Jupp has touched on the use of dehumidified atmospheres introduced into the cargo tanks. The drying of the tank surfaces to eliminate electrochemical corrosive action is a practical remedy, readily accomplished by commercially available dehumidification equipment. This procedure benefits the loaded, as well as empty, tanks. Corrosion during the actual time of tank cleaning is inconsequential, if the tanks are subsequently dried. Dry surfaces, free of moisture before loading clean cargo, are of major importance in this problem of reducing corrosion.

Mr. Jupp mentions the reduction of oxygen by the use of an atmosphere of flue gas as an important possible assistance in the corrosion problem where moisture is present. Perhaps the introduction of oxygen-free flue gas during ballast would prove effective. The advantages of inerting by introducing flue gas into the tanks to reduce the explosive hazard are of major importance. It is the combination of inerting, oxygen elimination and dehumidification, that should appeal to tanker operators interested in corrosion reduction and explosion hazard reduction by means of a thoroughly practical and economical system. Such a system is available for the interested tanker owner. The system is new, but the principal components

have had complete success in other shipboard applications for over 10 years.

To embody the advantages of using dehumidified flue gas, as well as an ample quantity of dehumidified air, for inerting, drying and ventilating, the washing and drying units employed in this system must be simple of construction and operation, practically maintenance free, space saving and economical. There are numerous types of drying units which have been installed on board ship to prevent cargo sweat, which use such agents as silica gel, activated alumina, glycol compounds, lithium chloride and refrigeration. It is the inherent nature of the selected drying agent which determines the essential features of design of the chosen drying equipment. This determines whether or not the equipment is fully suitable for a practical and economical installation, capable of drying both air and washed flue gas. A careful study of the advantages and disadvantages of the various drying agents leads to the belief that lithium chloride is the most practical agent for this purpose and this dessicant seems to be destined to meet the urgent need of economical dehumidification equipment for all tankers.

MR. PAUL FFIELD, *Affiliate*: The main point of my discussion will be regarding corrosion. The corrosion we were able to show was due to a galvanic effect. We were able to show that where pitting had occurred and it was very deep, electric currents were flowing from the pitted areas to the surrounding scale. The scale was behaving in a manner somewhat like mill scale, and whether it was mill scale or not, is beside the point. The important effect was that it was behaving galvanically and corroding at certain points.

The corrosion on this particular ship had formed a pattern and was confined to those areas exposed to direct washing, the top edges, the top surface of the rider plate on the keel. There was no corrosion underneath. It was confined to the top surfaces of piping, and again, no corrosion underneath. It was confined also only to tanks which had been ballasted after Butterworthing. On this particular ship the owner's practice was to ballast only center tanks. All were Butterworthed, however, on almost every trip. The wing tanks which were not ballasted were free from corrosion.

A sequence which we think was established in similar cases is this: that in the heavy oil trade the scale on the inside of the tank acts galvanically on steel. If we cover up that scale with a coating of oil and then ballast the ship, no corrosion will take place, but if we Butterworth off that oil film, that protective film, we will have possibly a comparatively large area of scale which can utterly corrode the steel at any breaks in the scale.

I think the high point of Mr. Jupp's paper is focussing of attention of the corrosion that he finds at hard spots in the structure and I think it may well be that the function of the hard spot is to break away the scale locally, permitting corrosion to occur at that point. For example, in Figure 3, Sketch A, he shows corrosion occurring on only one side of the plate. One should ask the question: Why doesn't it

occur on both sides of the plate? The answer may well be because only on that side was it exposed to Butterworthing.

I don't want to suggest that all corrosion is due to the type of thing I have mentioned. I do want to make the point, because it is important from the operator's viewpoint, that if it stems from a combination of ballasting and Butterworthing by reducing the Butterworth schedule, it is possible to reduce corrosion of this source.

I should like to make it clear I am not condemning Butterworthing, but merely pointing out that if we ask it to carry out its main function of cleaning the surface of the steel, we must be prepared for the fact that on occasion it can clean a cathodic area, which will corrode any exposed steel.

I think Mr. Jupp has done a splendid service in presenting this valuable information which he has collected over a number of years.

DR. R. W. MOORE, *Visitor*:* This is an interesting symposium. Mr. Jupp has pointed out very clearly the importance of corrosion fatigue in the early failures of tankers. The role of general corrosion in over-all tanker life has also been shown. The authors of Parts 2 and 3 of the symposium have shown how it is possible to reduce the general over-all corrosion in tankers by as much as 50 percent by the use of inhibitors and cathodic protection.

Most of you are aware of the part corrosion plays in the fatigue or endurance limit of metals. New metal of the type used in tanker construction has a well-defined fatigue life or endurance limit when tested in the laboratory in air under non-corrosive conditions. If, however, the metal is exposed simultaneously to corrosion and cyclic stresses, the resulting fatigue life is greatly reduced.

The so-called "hard points" or points of cyclic stress mentioned by Mr. Jupp are the result of corrosion fatigue. The question may well be asked as to how effective the corrosion mitigation measures mentioned in Parts 2 and 3 of this symposium will be in cutting down the corrosion fatigue in addition to reducing the general over-all corrosion. If we were starting with new metal, no doubt the use of corrosion inhibitors or cathodic protection would give an increased fatigue life over that now being experienced. However, the pertinent question which I would like to leave with you is, if the metal has already been subjected to some corrosion or corrosion fatigue, as is the case in most tankers, will the application of inhibitors or cathodic protection then be effective in reducing this type of failure?

REAR ADMIRAL C. D. WHELOCK, *Council Member*: It is not my purpose to discuss these fine papers but rather to add a bit of relevant information.

The Navy installed sea water displacement gasoline stowage systems in ships in the early twenties. In these systems the tanks are always full. As gasoline is drawn for use from the top of the tank, sea water in equal volume enters at the bottom. Air which

may get into the tank by entrainment in the sea water, or for other reason, is either dissolved or finds its way to the gasoline draw-off opening. Free oxygen, therefore is not present to support corrosion.

Observation after years of service in several of these ship systems revealed little or no corrosion of tank boundaries whether or not the surfaces were given a protective coating. Based on this experience the tanks in most of the large gasoline systems in our aircraft carriers, where contamination of the gasoline from any source must be avoided, are of the sea water displacement type and tank boundaries are uncoated steel. The carriers have been in service for from eight to 10 years and there has been little or no trouble from tank boundary corrosion.

MR. N. C. WILEY, *Member*: The excellent papers presented indicate that real advances have been made in minimizing corrosion of gasoline tank structure of ships. Although each points the way to different methods of corrosion control the respective authors agree that paint coatings offer little chance of achieving this end. However, it appears possible to cite experience which strongly indicates that there are paint coatings which may offer substantial corrosion protection and that inhibitors in cargo and cathodic protection systems may well be considered as secondary sources of protection. This viewpoint is that usually accepted in establishing other corrosion protection systems.

The specific paint system used by the Navy in its cargo gasoline tanks consists of successive coats of "Saran" paint (an approximately 20 percent solution of a vinylidene chloride/acrylonitrile copolymer, 1000 centipoise type, in methyl-ethyl-ketone). In the magazine "Corrosion," for June 1952, W. W. Cranmer gives a detailed account of the initial experimental work leading to the acceptance of this coating. Since the initial authorization for use, in December 1950, this type of coating has been applied to a varying number of tanks on 20 ships.

Since the coating was usually done in connection with structural alterations (addition of new cofferdams) no accurate, segregated, costs are available. It is only reasonable to assume, however, that the initial application costs of \$0.52 per square foot for material and labor (including staging costs) have been materially reduced as experience has accumulated. The likelihood that initial cost is greater than maintenance costs is strongly indicated by many inspection reports which state that after one year of service the original coatings are virtually intact, despite no change in gas-freeing procedures which were carried out with water temperatures ranging up to 180 degrees F and water pressures up to 165 psi. After four years of service, very little damage to the coating was incurred in the initial, experimental applications. If it is assumed that this cost of \$0.52 per square foot is increased to \$1.00 to include overhead and profit and further assuming a maximum replacement cost of 10 percent per year, costs to prevent corrosion by this means over a 10 year period run to approximately \$0.20 per square foot per year.

The advantages of a coating system for corrosion

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protection are obvious, but are worth setting down for convenient comparison with the other corrosion protection systems described in this symposium. Experience has shown that: Corrosion prevention is obtained for all structure in tanks irrespective of location and irrespective of loading (gasoline, partial or full, and ballast, partial or full). No maintenance of any kind by ships' force is required at any time. Necessary repairs to the coatings are made during shipyard overhauls at approximately 18 month intervals. Since the final coat is white, even a cursory inspection of the tank will indicate the presence of corrosion and the need for repair of the coating. No uncertainty exists as to the efficacy of the corrosion prevention system. It should be possible to clean tanks at lower temperatures and pressures. This point is discussed further in the following paragraph.

The presence of a non-porous coating should permit the use of lower tank cleaning temperatures and pressures. Gas freeing has been accomplished in one instance by simply flooding the tank with salt water; in another instance a water temperature of 72 degrees F was used. In view of this, changes in current mandatory instructions to use hot water at high pressures are being considered. Less severe requirements, when and if instituted, will considerably minimize a principal source of coating damage.

Experiments are also being carried out by the Navy with a dehumidified fuel gas system for the prevention of corrosion while tanks are carrying cargo. The system has been installed only recently and no operating experience is available.

MR. WILLIAM B. JUPP: The many discussions presented on these three papers have added considerable information on the subject of control of internal corrosion of tankers. All seem to be in general agreement that the galvanic action must be interrupted. The best method of accomplishing this under varying conditions is being studied carefully and progress is being made. This in conjunction with improved design already shows an increase in the life of the cargo spaces in tankers.

I take this opportunity to thank those who discussed this subject, particularly Mr. LaQue, for answering several specific questions which I felt needed clarification.

PRESIDENT KING: Thank you, Mr. Jupp.

MR. MALCOLMSON: Speaking for the authors of Part 2, all we have to say is that, in view of the fact that our approach to the corrosion problem is comparatively new, we must assume that there is not yet sufficient knowledge available for criticism. Under the circumstances, I do not think that we have anything further to offer.

PRESIDENT KING: Thank you, Mr. Malcolmson.

MR. A. B. KURZ: Mr. Green's comments are particularly welcome, because he has recognized the importance and emphasis which we have placed on the human element; namely, the cooperation and enthu-

siasm of the ship's personnel. Mr. Green has asked if we believe any part of the reduction in corrosion rates is attributable to the discontinuance of the process of tank washing previously used.

Yes, it can be stated definitely that the elimination of hot salt water tank washing at high pressure has removed one of the prime causes of accelerated corrosion rates. The corrosion control process described in Part 3 has almost eliminated tank washing on clean mixed product carriers. Wherever tank washing operations are required, they are being conducted with cold water rather than hot, with fresh water rather than salt water at relatively low pressure, (60 lb. vs. 180 lb.) rather than high pressure. Mr. Green's suggestion that complete evidence indicating favorable results might lead ultimately to a review of classification requirements is inspiring encouragement and adds impetus to establishing such results.

Although Messrs. Morrell have confined their comments to Part 1 of this symposium, we believe their discussion is a valuable contribution to the symposium. Therefore, we wish to submit several thoughts on their remarks.

First, Messrs. Morrell questioned how much reliance can be placed in any method or system of corrosion control in connection with increased scantlings to offset corrosion, and advised that it may be unwise to assume that any of them will wholly eliminate corrosion. One of the fundamental objectives which we sought to achieve in our corrosion control program was the 50 percent reduction and we believe that most of the programs that have been referred to in this symposium have used approximately the same objective. We believe our program exceeds this standard, but if it only meets our minimum requirement, we think it will permit the ship to operate without major plate renewals for its normal life, providing the corrosion control program is started when the vessel commences operation.

Second, although the increase in scantlings may solve the plate renewal problem, it does not solve the vital problem of ship's work load in tank cleaning. The quality of scale formed is a function of exposed area, not plate thickness. A $\frac{5}{8}$ -inch plate will corrode and produce as much scale as a $\frac{3}{4}$ -inch plate under like conditions. The ship's work involved in the washing of the tanks to remove residue held in the spongy scale, and removal of the scale itself when it falls to the bottom of the tank, still remains. Scale retaining residual product is the prime source of contamination or admixture. The elimination of the scale and all of the problems connected therewith can be accomplished only by corrosion control methods.

Third, from an economic standpoint, we believe that although the actual cost of a heavier plate may be relatively small, when all the miscellaneous charges, such as added interest on construction loans, amortization and interest over the life of the vessel and the cost of scale removal, are calculated, there will be close balance with the routine maintenance expenses of a corrosion control program.

Fourth, it is noteworthy that Messrs. Morrell favor the specific allocation of tanks for ballast and non-ballast. In practice we have proved this desirable, but

for different reasons and our program emphasizes the maximum allocation of ballast tanks because of the simplicity of applying corrosion control procedure therein; and further because it is our belief that corrosion rates are lower in ballast tanks.

There are a few comments, applicable to the recommendations presented by Messrs. Colvin, Cooper, Dean and Duly, which we believe worthy of further study.

The effectiveness of CO₂ and dehumidified air in enclosed and confined spaces is well established and recognized. The problem is the proper adaption of the systems to the non-ballast compartments of tankers. In order to use CO₂ or dry air within cargo tanks efficiently, a foolproof closed venting system is necessary to contain the dried air and keep out moist atmosphere. Experiments and tests are being conducted in an endeavor to obtain a completely closed venting system. When this problem is solved it will remove one of the hurdles in the way of dehumidification.

Another factor is the complete removal of residual cargo, wash water or ballast from the cargo tank prior to the introduction of dried air or CO₂ gas. The drier the tank at the start, the more effective the dehumidification will be. Some of the developments indicated in Part 3 of this symposium would be equally helpful in removing this hurdle.

Mr. Colvin indicated that Butterworthing need not be abandoned. This may be quite true, however, if some form of washing is required, the work load of the ship's force remains heavy. This is an overtime operation which adds considerably to the operating expenses. Messrs. Colvin, Cooper, Dean and Duly are to be congratulated for their contribution to this symposium and for the progress made thus far with dehumidification as a means of corrosion control.

Mr. Roeske has recognized the importance of adequate coverage of any inhibitor applied by a spray system and has suggested certain remedies in the form of bulb plates and angles which the naval architects and shipbuilders may contribute to the solution of this problem. The adoption of corrugated and fluted type bulkheads in lieu of flat plate bulkheads with stiffeners has been an important step in this direction. There still remain some steel structures which might be rearranged without sacrifice of strength and yet expose the flat surfaces for treatment, such as the proper position of brackets and flanges so as to minimize their screening effect.

Considering the general questions—

1. *Has it been possible to arrive at a definite conclusion as to how much anodic surface is required for given tank bottom and surfaces?*

Part 3 outlines the number of steps that were taken to increase the number of anodes at various intervals at arrive at the proper number to achieve uniform and complete protection. This experience forms a sound basis on which to determine the anodic requirements for any given tank.

2. *Does there appear to be a limit in reduction of corrosion control rates irrespective of anodic surfaces?*

From our understanding of the galvanic action which takes place and our experience confirms this, there is an upper limit after which any increase in anodic surface will have no effect. However, the rate of dissipation of the individual anodes will be reduced accordingly. For example, if after initial polarization a center tank on a T2 tanker is equipped with approximately 60 anodes with an estimated life of three years; if this number were increased to 120 anodes, we believe the coating and protection would be the same, but that the life of the anodes would be increased twofold.

Regarding the chemical composition of the anodes, there is a basic standard specification for a sacrificial anode which is readily available for the commercial market. The experiments did not include trials with any metal other than magnesium. We are aware also that magnesium of a higher purity is readily available.

3. The final question which Mr. Roeske has raised concerning distribution of anodes in relation to severity of corrosion in different parts of the tank is quite familiar to us. A typical example was our observation that the anodes at the extreme bottom of the tanks were being dissipated at a faster rate than the upper anodes, and the ship's structure was not being coated with a calcareous deposit in this area. Therefore, we doubled the anodes here.

The discussion of Messrs. LaQue and May, although primarily concerning Part 1 of this symposium, is of such value and interest that we wish to take this opportunity to express our appreciation for their valuable contribution to this symposium. Generally the answers to all of their questions confirm, with authority, many of the thoughts which we have had, and on which we have based our corrosion control procedure.

Specifically, the answers to their questions (1) and (5) confirm and establish a definite need of allocating tanks specifically for ballast and non-ballast. Obviously the general practice in the past has been haphazard in the assignment of ballast and non-ballast and for this reason it has been difficult to measure, in actual operations, the wastage of a particular bulkhead, and to assess the effect of ballast or vapor. The two-thirds to three-fourths estimate of corrosion on the empty side, as compared with the ballast side, is within the range of our estimates and observations.

In paragraph (D) of the comments, the discussers point out that there may be problems in locating the anodes so that sufficient current for protection will flow to corners and recesses. Investigation of our installation indicates that the anodes have been distributed to take care of this situation and as it has been pointed out, considerable actual experimentation was necessary to achieve proper positioning.

We concur with Mr. LaQue's conclusion that the best results are likely to be secured by the application of several remedial measures, and we might add that the measures employed may vary in their degree and number depending upon the trade of the vessel.

We regret that a copy of Part 3 was not available to Captain Lamb and Mr. Rowe, however, we do appreciate their comments as a result of inspection of the S.S. *Cherry Valley* in June 1951 when the vessel was in Galveston, Texas.

Mr. Parker's compliments concerning the three papers are, of course, welcome, but in the succeeding paragraph he states that none of the methods has been established as economical, simple to apply, sufficiently effective and reliable under sea-going conditions. We realize that every one has a different standard of values, and it would have been more helpful if Mr. Parker had pointed out specifically where we had neglected to establish satisfactory standards of achievement; for indeed, the establishment of the seven standards of objectives as set forth in the first part of Part 3 were the only means of measuring the success of our program that we could conceive. We shall welcome any constructive suggestions for the establishment of uniform standards.

The actual observations which Mr. Field has reported in his discussion concerning the corrosive effect of the Butterworth and ballast operations is a valuable confirmation of the principles established in Part 1 and of the basic procedures which we outlined and adopted in Part 3.

Dr. Moore's discussion has raised several interesting questions directed to Parts 2 and 3 of the symposium.

In answer to the first—namely, will the corrosion mitigation methods reported be successful in cutting down corrosion fatigue in addition reducing further over-all corrosion? We doubt that there are any concrete figures on which we could establish an answer. However, from observation and study, we believe it fair to say, and reasonable to expect, that any hard spot will be subject to normal atmospheric or galvanic corrosion as any other portion of the tank. In addition, it is subjected to greater corrosion fatigue as the particular adjoining and supporting structure is weakened by normal corrosion; thus, corrosion fatigue is accentuated and becomes more serious. Therefore, if corrosion mitigation procedures reduce the normal corrosion by 70 percent they leave only the corrosion fatigue problems in the hard spot and the rate of corrosion at this point is not increased by the general weakening of the surrounding structure.

Dr. Moore's second question is: If the metal has already been subjected to some corrosion or corrosion fatigue, as is the case in most tankers, will the application of an inhibitor or cathodic protection then be effective in reducing the type of failure? This question is also a difficult one to answer accurately. However, it is our belief that the inhibitors or cathodic protection, properly applied, will be effective in reducing failures due to corrosion fatigue. Their effectiveness is a matter of degree, and may be proportionate to the wastage of the plates at the commencement of mitigation procedures.

We were very pleased to read Mr. Wiley's discussion reporting on the recent advances made with specific painting systems, and we quite agree with the conclusions which he has reached regarding the reduction of cleaning of tank surfaces and reduction of all of the other operating problems. However, we believe that these are only true in the case of a ship operating in single petroleum product service, i.e., continuous operation in the transportation of full-load gasoline service. Many of the ships today, operating in commercial trades, carry five to eight separate products on the same voyage.

As far as we know, no coating has been developed which is suitable for the variety of products that have to be carried in various quantities. Flexibility of cargo compartment allocations is necessary. Often the use of a conventional paint type coating limits the number of products which can be carried. Where coating failures occur, corrosion attacks are concentrated, and proper touch-up or recoating is difficult.

We have had experience with the application of coatings of tank interiors, and the indications are that a cost of approximately \$2.00 per sq. ft., or higher, would be more reasonable to use for estimating such a job. It is also a time-consuming operation, and in order to be effective, it must be done 100 percent efficiently. Our experience indicates that one small compartment of approximately 13,000 sq. ft. required 11 days to be metallized with a zinc lining, the application of which in many respects may be quicker than a vinyl or plastic coating because of the single coat application.

In conclusion, it is our belief that protective coatings are a very effective means of reducing corrosion in specific specialized applications, but until more economical means of surface preparation and coating application can be developed, protective coatings are too expensive and time consuming to consider for over-all fullscale corrosion control.

PRESIDENT KING: Thank you, Mr. Kurz. May I express the deep appreciation of the Society to the authors who have contributed these papers to make possible this excellent symposium. A large amount of work is represented here and it is particularly gratifying to have it contributed by the operators. This Society is composed of operators and shipbuilders as well as other technical people and it is a fine thing for the Society to have these authors provide us with such a splendid group of papers. On behalf of the Society I thank you all very sincerely.

Cable Sheath Corrosion and Prevention*

By B. B. REINITZ

FOR SOME TIME conservation of natural resources has been uppermost in the minds of those responsible for this country's well-being. Since some metals are in a limited supply, particularly those in use for electric power cables, their conservation is of growing importance. It has been estimated that corrosion of buried structures is costing industry about a billion dollars annually.¹ Part of this loss is shared by the various utilities. Considering that the United States is becoming more and more dependent on foreign sources for an adequate metal supply, it is desirable to strive in every way possible to practice conservation. There is hardly a better and more effective way to practice conservation of metal structures than protecting them against corrosion. This paper deals with corrosion of lead sheathed cables and means of prevention and, in addition, the cost of replacement and service interruptions which are factors deserving serious consideration.

Before recommending protective measures, it is well to review the various phases of corrosion, particularly those of relatively recent investigations. While the causes of cable sheath corrosion and their prevention have been previously described² further elaboration based on field experience since then and recent experimental data is desirable. Apart from an interest in the usual chemical and stray current damage, the corrosion engineer is more concerned than ever with losses resulting from galvanic action, microbiological environment, scoring and from salts used for de-icing traffic thoroughfares and also, to a lesser extent, corrosion due to mechanical stresses, electroendosmosis, cement arc proofing in manholes and alternating current.

Galvanic Action

It is well known that when two metals having widely different potentials are connected together in an electrolyte, the more negative metal corrodes more rapidly than when uncoupled. Attempts have been made to predict the behavior of one metal in contact with another on the basis of the electromotive series of metals. However, owing to variations in chemical environment and modifications of the physical structure of such metals as lead and aluminum when used as cable sheathing, a reversal of potential can occur. This, together with the fact that many active metals in certain environments become passive is an indication that the electromotive series has only limited application. As an example, buried lead cable is normally cathodic to iron or steel but in alkaline waters, it is anodic. For this reason it is the galvanic series which deserves consideration where the measured po-

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Abstract

Two-thirds of cable failures are attributable to corrosion and mechanical damage. Replacement costs and service interruptions are considerations of prime importance. Conservation of limited metal resources is an additional reason for seeking improved methods of preventing corrosion.

While stray current corrosion has decreased in recent years, galvanic and concentration cell corrosion have multiplied. Also, other causes of corrosion, such as microbiological action, scoring, de-icing by means of salts, electroendosmosis, cement arc proofing and alternating current are receiving increased attention.

Cathodic protection, when used for cable sheathing, serves primarily as a means for mitigating rather than completely eliminating corrosion and its applications are limited. On the other hand, a suitable covering over the lead sheath offers a dependable and more certain method of protection for underground cables.

Nearly twenty years of service experience without a recorded case of sheath corrosion have established the value of a thermosetting covering having a fiber-free, homogeneous wall of properly compounded neoprene. Recently adopted manufacturing methods have led to an improved covering, possessing a more uniform wall thickness, greater density and freedom from laminations.

tentials of metals are used as a basis for the evaluation of corrosion.³ In addition, consideration also must be given to the fluctuating and variable environment which is a dominant factor. Therefore, cable sheathing metals such as lead and aluminum may corrode even when functioning as cathodes under conditions of high current density.⁴

Because many engineers have overlooked these phenomena, considerable galvanic corrosion is being experienced now. The situation has become serious where electric railways have been eliminated. Rails used as a negative return and also as a medium of electrolysis drainage from cable sheaths are no longer available and the cathodic protection they afforded is lost. Although stray currents resulting from leaks of grounded DC electrical distribution systems have been lessened, corrosion due largely to galvanic action is no longer suppressed. This is aggravated by the use of copper coated ground rods and bare copper grounding cables at generating plants and substations.

*A paper presented at the Ninth Annual Conference, National Association of Corrosion Engineers, Chicago, Ill., March 16-20, 1953.

tions; and also as a result of the use of bare copper neutral cables in duct lines as well as copper ground rods in manholes.⁵ Moreover, cable sheaths generally are connected to the ground bus at stations and substations and thus form a large galvanic cell.

Microbiological Environment

Anaerobic corrosion is caused by specific types of bacteria which are active in environments free of oxygen. Other factors are moisture content, alkalinity and pH. The bacteria thrive where there is an abundance of organic matter and in the presence of calcium and magnesium salts.⁶ While the exact mechanism of bacterial corrosion remains to be clarified there are various theories to explain this type of corrosion. The first theory, originated in Holland, visualized the removal of cathodic hydrogen by the sulfate reducing bacteria and the acceleration of the corrosion rate as the result of this depolarization. In another view, the bacteria are regarded as influential in reducing the oxygen content of the duct or soil water at local points with the resultant formation of differential aeration cells. The presence of microbiologically produced sulfide on the lead is evidence of a reducing environment because the sulfate reducers are active only in absence of oxygen.⁷

According to observations made by F. E. Kulman,⁸ cables removed from bottom ducts in the tide water areas of New York City often show pitting without the usual white or red corrosion products, but with a black color instead. Where cables were submerged, the odor of hydrogen sulfide gas was noticeable. This resulted in corrosion of copper bond wires and tubing in manholes.

To simulate the corrosive condition, Kulman constructed a miniature duct 18 inches long of cast concrete and provided it with four levels of ducts (Figure 1). Lead sheathed cables of a known weight were placed in the ducts. Mud and water from a manhole, enriched with sodium sulfite was packed around the cable in the bottom duct which was then sealed. All cables were bonded electrically and the duct bank placed in a tank of tap water.

After 22 months, it was reported that the cable at the bottom duct which had the least aeration, was anodic to the other cables by approximately 0.1 volt. The highest current flow between cables was 1.3 milliamperes; the polarity was such as to cause corrosion of the bottom cable.

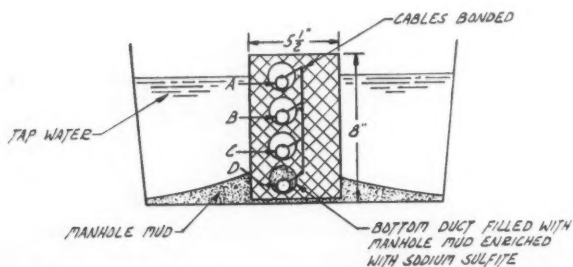


Figure 1—Test set-up for microbiological corrosion.⁸ (Started March, 1938, completed January, 1940.)

TABLE I—Microbiological Corrosion (Kulman)
Summary of Test Results

Cable Position	Weight, Grams			Corrosion	
	Initial	Final	Loss	Color	Pitting
A Top.....	1085	1087	...	White	Not pitted
B 2 Top.....	1088	1088	...	White	Not pitted
C 2 Bottom.....	1111	1113	...	White	Not pitted
D Bottom.....	1121	1111	10	Black	Pitted $\frac{1}{8}$ "

TABLE II—Microbiological Corrosion (Kulman)
Corrosion Product—Cable D

	Percent by Weight
Loss on Heating at 105° C.....	10
Material Soluble in Water.....	41
Basic Lead Carbonate.....	22
Lead Sulfide.....	27
	100%

TABLE III—Microbiological Corrosion (Kulman)
Composition of Mud from Bottom Duct

Loss on Ignition.....	24.3
Silica SiO ₂	30.0
Iron and Alumina as Fe ₂ O ₃	17.1
Calcium as CaO.....	10.6
Magnesium as MgO.....	5.8
Lead.....	6.8
Sulfur as Sulfide.....	1.0
Sulfate as SO ₃	3.4
Carbonates.....	Present
	99.0%
Water Insol.....	80%
pH.....	8.4

TABLE IV—Microbiological Corrosion (Kulman)
Composition of Water from Tub

	Parts per Million
Carbonate as Na ₂ CO ₃	392
Bicarbonate as NaHCO ₃	1856
Chlorine as NaCl.....	230
Sulfate as Na ₂ SO ₄	1456
Sulfide.....	None
Lead.....	None
Iron and Aluminum.....	Trace
Calcium and Magnesium.....	Trace
Phosphate.....	Trace

After completion of this experiment, the cable sections were removed, examined and reweighed. The non-aerated cable from the bottom duct showed pitting to a depth of 1/32-inch and a loss of 10 grams from an area of 50 square inches as well as a black color while the other cable sections showed no loss in weight (Table I). Moreover, the bottom cable disclosed a continuous black coating which showed on analysis 27 percent lead sulfide apart from the other corrosion products (Table II). Even the composition of the mud from the bottom duct disclosed the presence of sulfide (Table III). The water from the tub contained no sulfide but showed 1456 parts per million of sulfate (Table IV).

While no count was made of sulfate reducing bacteria, it is likely that they were present in the mud. It would seem from this experiment and a review of the literature that bacteria caused the anaerobic condition. As the reducing intensity of the soil environment increases, the environment becomes favorable for the development of the sulfate reducers.

Scoring

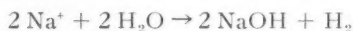
The effect of scoring on corrosion of cable sheaths

often is overlooked. The rate of corrosion may be accelerated greatly when mechanical or abrasive conditions are encountered.⁹ This is particularly true when at times deep furrows in sheaths result from scoring during installation. While sheaths are designed to take care of scoring by as much as 15 percent of their thickness, severe scoring not only weakens the sheath mechanically but creates anodic areas for the initiation of progressive deterioration in a corrosive environment.

A good example of the effect of this type of corrosion is shown in Figure 1A. After only four years' service, failure resulted to a 15KV paper impregnated lead sheathed cable from corrosion accelerated by scoring. The corroded area coincided and was in line with a score mark in the lead.

Salts Used for De-Icing

For some time there was a prevailing opinion that cables maintained at a negative potential with respect to other structures were immune from corrosion. Such is not always the case when salts are used for de-icing because severe cathodic corrosion due to electrochemical action may take place as a result of the formation of sodium hydroxide.¹⁰ This type of corrosion is becoming increasingly serious¹¹ particularly in metropolitan areas where salts are used on snowy and icy roads. As the street brine seeps underground, contamination of cable manholes and duct lines results. When there is a current flow, transference of ions may lead to a high concentration of alkali around cathodic areas of lead cable sheaths, especially if the cathodic protection current is excessive.



Thus even though a lead sheath is cathodic, it can be severely attacked by sodium hydroxide.

Mechanical Stresses

It is well known that stresses render metals susceptible to intergranular corrosion when subjected to a corrosive environment. Also marked stress gradients can exist across grain boundaries and highly localized severe stresses can be formed during strain hardening, cold working, abrasion and scoring.¹² Furthermore, corrosion fatigue cracks develop when a metal is subjected to alternating stresses in a corrosive environment. The resistance to fatigue cracking is further lowered by stress concentration at surface defects. While stress is not essential in early stages it must coincide with corrosion in later stages to cause fracture. Moreover, because anodic corrosion under stress conditions is autocatalytic, an attack once started at a certain spot continues at that point until severe pitting takes place.¹³

Electroendosmosis and Cathodic Protection

Electroendosmosis is migration of water or other liquid through a porous membrane under the influence of an electrical potential gradient. When liquid is in contact with a solid phase through a porous diaphragm, the two phases acquire unlike charges, giving rise to a potential difference between them.



Figure 1A—Corrosion accelerated by scoring.

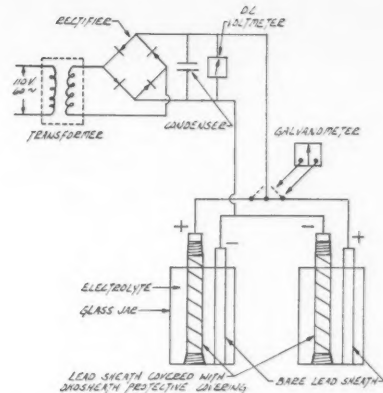


Figure 2—Electroendosmosis test set-up for Okosheath protective covering.

Because a liquid is free to move, it tends to migrate under the influence of an electric field. Rate of flow varies with current, nature of diaphragm, nature and amount of dissolved substances in the water and the temperature.

According to Maitland¹⁴ the volume of current resulting from cathodic protection applied by means of rectifiers frequently is greater than is desirable, resulting in electroendosmosis in the protective covering. It was called to the author's attention also that accelerated tests were conducted by another investigator under conditions of excessive current on neoprene-type slab specimens over metal plates which resulted in blistering. The tests consisted of measuring insulation resistance of the covering and current collected by the protected metal under continuous cathodic energization at direct current potentials.

To determine if blistering resulting from electroendosmosis is characteristic of neoprene coverings, an independent experiment was conducted on a neoprene compounded covering known as Okosheath. Two 14-inch samples were kept under test at 6 volts cathodic and measurements of current collected and covering resistance made periodically. The electrolyte was a salt solution having a resistivity of about 26 ohm-cm. After a little over eight months' test it was reported that there was no change in the electrical resistance of the covering and that latter was still extremely tough.

Electroendosmosis tests were also carried out in Okonite Callender Cable Co. laboratories with speci-

mens immersed in tap water containing 0.1 percent sodium sulfate. Tests were conducted at both room and elevated temperatures with the one length of lead sheath continuously at an impressed negative potential of approximately 9 volts dc and a second continuously at an impressed positive potential of approximately 9 volts dc. After 602 days at room temperature and 244 days at elevated temperature there was practically no change in resistance of the neoprene compounded covering known as Okosheath and no difference between the positive and negative specimens. Moreover, there was no indication of blistering. Figure 2 shows the test set up and Tables V and VI, give the test results. Other samples also were tested at room temperature in a 3 percent salt solution with similar results.

Asbestos-Cement for Arc Proofing in Manholes

Generally a mixture of asbestos-cement and asbes-

TABLE V—Summary of Electroendosmosis Tests on Okosheath Protective Covering
Electrolyte Resistivity—500 ohm-cm

Elapsed Time Days	Ambient Temperature °C	D-C Volts	MICROAMPERES	
			Protected Sheath Negative	Protected Sheath Positive
0	22	9.3	0.75	0.375
63	20	9.3	0.50	0.75
156	24	9.7	0.25	0.25
219	23	9.4	0.25	0.25
330	22	9.1	0.25	0.25
602	19	9.4	0.25	0.25

TABLE VI—Summary of Electroendosmosis Tests on Okosheath Protective Covering
Electrolyte Resistivity—320 ohm-cm

Elapsed Time Days	Ambient Temperature °C	D-C Volts	MICROAMPERES	
			Protected Sheath Negative	Protected Sheath Positive
0	48	9.7	5.75	4.75
30	52	9.5	2.50	2.25
62	49	9.4	2.00	2.00
131	49	9.1	1.25	1.25
244	48	9.1	2.00	2.25

TABLE VII—Composition of Corrosive Water from Manhole in Which Partially Submerged Lead Sleeve Had Been Disintegrated

	Parts per Million
Total Solids	645
Loss on Ignition*	70
Silica—SiO ₂	22
Iron Aluminum Oxide—FeAlO ₃	15
Calcium Hydroxide—Ca(OH) ₂	251
Calcium Chloride—CaCl ₂	206
Calcium Sulfate—CaSO ₄ ·2H ₂ O	230
pH—8	—

* Organic matter, combined water and carbon dioxide.

TABLE VIII—Composition of Manhole Sediment (Dry Basis)

	Percent
Loss on Ignition*	13.10
Silica—SiO ₂	32.36
Iron Oxide—Fe ₂ O ₃	9.38
Calcium Hydroxide—Ca(OH) ₂	0.40
Calcium Chloride—CaCl ₂	0.13
Calcium Sulfate—CaSO ₄	1.16
Calcium Carbonate—CaCO ₃	43.63
Magnesium Carbonate—MgCO ₃	13.10
pH—8	—

* Organic matter, combined water, carbon dioxide, carbonaceous ingredients and oily hydrocarbons.

tos tape are used for arc proofing. A number of severe corrosion cases have been called to the writer's attention. It is well known that in the presence of water the lime in the cement is converted into calcium hydroxide which together with other compounds present is highly conductive and very corrosive. Under conditions of differential aeration, concentration cells are formed with consequent corrosion of the pitting type. It is significant that even after three years' service, when most of the calcium oxide in the cement has been converted into harmless calcium carbonate active lime is still present as shown in Table VII.

Thus, the conditions generally encountered are those in which part of the arc-proofed lead cable sheath and sleeve are in contact with moist manhole supports while resting in and out of pools of stagnant sediment (Table VIII). Concentration cells are established in which anodic areas undergo severe corrosion. This condition is aggravated where bond wires are involved, as self-generated currents are set up by the dissimilar metals when in contact with a highly conducting electrolyte such as calcium hydroxide and chloride.

Alternating Current

That alternating current corrosion is significant was demonstrated by two insulation failures on 13KV single conductor lead covered power cables. Their case histories showed that failure was due to corrosion of sheaths produced by a combination of galvanic and rectified induced alternating sheath currents. Extensive field and laboratory experiments indicate that alternating current corrosion is caused by a process of rectification in which alternating voltages of low value induced in the sheaths by the load current in the cables result in alternating currents between sheaths and ground. These are converted to direct current which produces anodic corrosion. Alternating current corrosion is most pronounced when cables are new and when they are at elevated temperatures. With time, destructive effects of rectification decreases and eventually ceases as a result of reversal of polarity.¹⁵

At room temperature the corrosive effects of alternating current are extremely small and hardly significant. Not until a temperature of 40 degrees C is reached does it become important. Above 40 degrees C the rate of corrosion resulting from alternating current was greater than that of chemical corrosion. Moreover, above this temperature it begins to accelerate the rate of chemical corrosion. At 70 degrees C the rate of corrosion is about 30 percent greater than that of chemical corrosion. The rate of corrosion increased by 20×10^{-6} per square centimeter, an increase further accelerated by a rise in temperature.¹⁶

Prevention of Sheath Corrosion By Means of Cathodic Protection

From a theoretical standpoint the prevention of corrosion would not be difficult if the electromotive series of the elements and Faraday's laws were all that need be taken into account. However, under field conditions where there is non-uniformity in

physical condition of metal, variation in environment and other structures in close proximity, the problem of corrosion prevention becomes at times a very difficult and complex matter and must be resolved into its principal components.

Since corrosion is recognized as an electrochemical process, some corrosion engineers feel that galvanic cells causing corrosion can be stopped by polarizing cathodic areas until their potential becomes equal to that of the anodic areas. This method of prevention is generally referred to as cathodic protection and may be achieved either by means of rectifiers or by use of sacrificial anodes.

Cathodic protection has met with considerable success on long pipe lines and cable sheaths where other structures were not involved. It also has been helpful on old corroded lines which are both bare and poorly coated and on well-coated pipes to insure against "holidays" and possible future breaks in the coating.¹⁷ This does not alter the fact that where dissimilar soils or strong electrolytes are involved there is little that can be done except to protect the sheath with a substantial protective covering. Considering the many factors contributing to corrosion, many of which are unpredictable in advance of construction, the use of high grade covering appears to be economical.¹⁸

In metropolitan areas and in large cities where a number of structures are involved, poorly designed and constructed cathodic protection installations actually can do considerable harm. This is due to the fact that when cathodic protection is applied to a buried structure some of the protective current will stray through the electrolyte to nearby structures, and especially to lead cable sheaths. For this reason, under congested conditions cathodic protection finds limited application.¹⁹

In an extensive investigation on cathodic protection²⁰ the mitigation of stray current electrolysis in congested areas is still considered a major problem. In fact, it is recommended that when newly installing or replacing buried structures, consideration be given to the use of coatings where cathodic protection systems are likely to be in operation on adjacent structures. Moreover, difficulties arise from the accidental contacts with water pipes or unprotected gas piping which are expensive to locate and isolate.²¹

The sacrificial anode method is based on the galvanic cell principle in which one metal is sacrificed to preserve another. In this system galvanic anodes rated high in ampere hours per pound are placed alongside structures to be protected and spaced according to current requirements. The use of galvanic anodes is limited, however, because they function effectively only in presence of moisture and in low resistivity soils. In one installation where a large number of zinc anodes were used, some were active for years while in other locations others became passive in a year or two.²¹

In a recent investigation on potential measurements for cathodic protection design, it was concluded that cathodic protection is still more of an art than a science. The corrosion engineer must use his



Figure 3

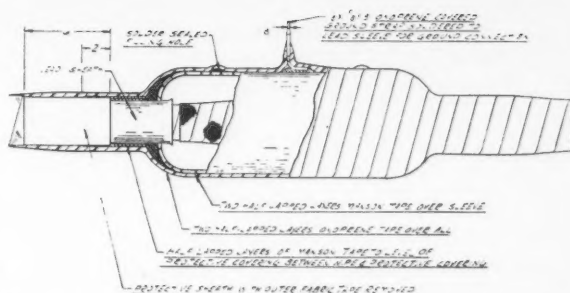


Figure 4—Application of Okosheath tape over metal sleeve splice.

ingenuity and experience in the face of puzzling and often contradictory results.²²

Prevention of Sheath Corrosion By Means of a Neoprene Covering

In a report on lead vs. non-metallic sheathed, underground cables,²³ the conclusion was reached that a lead sheathed cable with a suitable covering over the lead still offers the safest construction for underground use, regardless of the system voltage. Moreover, it was indicated the most positive type of exterior protection seems to be afforded by a neoprene jacket. That this type of covering is effective is indicated by the fact that in some cable plants a substantial proportion of lead sheathed paper insulated cables are furnished today with this type of protective covering.

It is reported that 66 percent of cable failures are due to corrosion and mechanical damage.²⁴ Many years of experience show that a properly processed neoprene covering combats these two causes. Neoprene has withstood the severe conditions imposed by duct and underground use to the extent that after almost 20 years of service no case of sheath corrosion has been reported on any cable having a covering incorporating a specially compounded and homogeneous wall of vulcanized neoprene firmly bonded by vulcanization to the metal. This uniformity and homogeneity is brought about by application of a solid wall of non-flammable, moisture and heat resistant neoprene compound by the longitudinal strip process

(Figure 3), giving assurance of uniform wall thickness, high density and freedom from laminations. Immediately after the covering is applied the completed jacket is spark tested according to a standard procedure for detection of "holidays."

Prevention of Corrosion in Manholes

Corrosion in manholes under asbestos cement arc proofing can be prevented by application of a neoprene tape free of fibrous material. It is resistant to heat, moisture, ozone and weather extremes.

Neoprene tape gives lasting protection to all types of cable splices where a neoprene protective covering over cable sheath is used. Field splices are standing up under every type of installation condition. Figure 4 shows the method of applying neoprene tape over a metal sleeve splice.

Conclusion

While a corrosion survey for cathodic protection will likely indicate the conditions existing at any given time, the variation in environment surrounding an underground cable system has led most utilities to consider it a sound investment to use a time-proved protective covering for the prevention of corrosion. Such a covering should be selected for its mechanical and dielectric strength as well as for its homogeneous structure and moisture resistance. Furthermore, it must be stable, inert and firmly bonded to the sheath. In addition to composition and processing, application method deserves serious consideration.

It is well to point out that whereas most corrosion engineers are largely concerned with the control or mitigation of corrosion, the materials recommended over cable sheaths are for the prevention of corrosion. They are based on many years of dependable performance. A neoprene protective covering such as Okosheath is effective in preventing corrosion and also in preventing abrasion and scoring of cable sheaths. Moreover, it increases life expectancy of cable by increasing resistance to manhole bending fatigue and acts as a reinforcement against internal pressure.² Considering the cost of replacement and service interruption the protection of the ever expanding network of underground power cables cannot be neglected.

DISCUSSION

Discussion by J. F. Hirshfeld, The Hinchman Corp., Detroit.

Mr. Reinitz is to be commended for his excellent review of the various factors causing corrosion of lead cable sheaths. Recognition of many of these factors is frequently neglected even by experienced designers and it is well to have them summarized concisely in one paper.

We are particularly interested in the data indicating that electroendosmosis is not a factor to worry about unduly with a properly designed and fabricated Neoprene sheathed cable. These data indicate that forced drainage currents of normal density can be applied without danger to systems that are part Neoprene sheathed and part exposed lead as is frequently the case where Neoprene jacketed cable has been

used for replacement of portions of an underground system.

The comments on asbestos-cement arc proofing are also worthy of special mention. Not only are such coverings often a cause of corrosion as is outlined in the paper, but they are of questionable utility as arc proofing in the saturated and damaged condition in which they are frequently found in manholes. Meticulous design and a good maintenance program, of course, can do much to overcome these objections.

There is no doubt that Neoprene jacketed cable is an excellent product and that, like all good engineering materials, it will find an increasing number of uses for underground construction. We have frequently found that the price differential between it and ordinary lead sheath cable is justified by environmental conditions. However, we have also found that indiscriminate substitution is not always the answer. Replacement of a damaged cable section by a Neoprene jacketed cable may very well transfer the critical corrosion area to some other remaining lead sheath section of the underground plant structure, thereby accelerating deterioration of valuable underground property. Consequently, the designer must take this factor into consideration in his analysis of a corrosion problem involving even a modest underground system. With large systems, the results of such substitution could have considerable consequences and a combination of corrosion mitigation techniques is often the proper answer. Such a combination of techniques may involve breaks in electrical continuity between jacketed and unjacketed section of the cable sheaths and the use of cathodic protection on the remaining lead covered sections. As with most engineering problems, there are usually several technically satisfactory solutions and the proper solution for a given case is dictated by economic values.

The increasing incidence of corrosion in most metropolitan areas with the removal of forced drainage provided by the transit systems is well known and is well stated in this paper. Since the value of this form of cathodic protection which frequently involves currents and voltages of sizeable magnitudes and rapid fluctuations has been so well established by experience, it is our belief that the case for planned cathodic protection in metropolitan areas is often somewhat understated even by engineers who have worked for years with forced drainage systems.

The potentials of all structures involved in a complex cathodic protection system using either galvanic anodes or external current sources are capable of close regulation by proper design and careful field engineering. Consequently, cathodic interference problems and excessively negative potentials on lead cables can be more easily handled by a cathodic protection system purposely designed than by one dependent on the fluctuating conditions of a transit system.

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Radiography as an Aid in Corrosion Studies*

By H. A. LIEBHAFSKY and A. E. NEWKIRK

Introduction

IN ROUNDING OUT an earlier investigation in which the rate of pitting in stainless steel was determined by x-ray methods, several series of radiographs were obtained that show the value of such methods in qualitative corrosion studies. Representative radiographs are reproduced herein above captions giving the experimental conditions. These radiographs demonstrate why it is desirable to supplement visual observation or photography by this x-ray technique.

Experimental

Stainless steel plates ($2 \times 2 \times 0.025$ inches, approximately) of three types (302, 317, and 347) were wet with alcohol, wiped dry and immersed in aqueous solutions containing 10 percent by weight of $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$. In most experiments the plate was set at an angle near 10 degrees from the vertical in a 400-ml beaker containing 300 ml of this solution at room temperature. Other conditions of immersion are described in the captions. Only one radiograph was made on a sample.

Ferric chloride solution was selected because it is known to be a good reagent to produce pitting in stainless steels. The chloride ion not only penetrates the protective film, but it tends to concentrate in the anodic pits, where it promotes the anode reactions in various ways. Moreover, ferric ion can be readily reduced at cathodic areas adjacent to the pit. Of course, ferric chloride solutions are more complex than this simple picture implies. They contain complex ions, they are acid by hydrolysis (the solution used had an initial pH near 1.3 at room temperature), and they can act as oxidizing agents even though no cathode exists.

When pronounced corrosion occurs during stagnant immersion, the dense, greenish solution containing the corrosion products usually flows downward in the region next the sample and accumulates at the bottom of the beaker, whereupon the boundary between the green and the ferric chloride solutions gradually rises. In some experiments this boundary reached the top of the sample in a day.

At the end of the immersion period each square of stainless steel was washed with warm water, dried and submitted to the Schenectady Works Laboratory for a contact radiograph. Typical exposure conditions for these radiographs were: Source, special beryllium-window x-ray tube; distance from source to film, 72 inches; peak tube voltage, 95 kilovolts; tube current, 5 milliamperes; film, type "M"; exposure time, one minute.

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Abstract

The value of radiography in qualitative corrosion studies has been demonstrated by applying this x-ray technique in an investigation of the corrosion of three types (302, 317, 347) of stainless steel by ferric chloride solution. Parallel photographs and radiographs were obtained for comparison. The radiographs show striking differences in the corrosion patterns for the different steels under different conditions.

Rotation of samples was carried out as follows. The stainless steel plate was inserted in a holder, a slit polystyrene rod. The holder was centrally mounted in a rubber stopper that closed a pint jar filled with 10 percent ferric chloride solution. Owing to the manner of mounting, the holder was pinched slightly, so that polystyrene was nearest the sample at its top edge. The jar was rotated at 90 rpm about the long axis of the holder.

Discussion of Results

Photography and radiography are, of course, complementary. Together they can reveal changes that occur both on the surface and in the interior of the specimen. To be sure, probing followed by photography can often give evidence of interior changes also, but such evidence will be less certain and less complete than that yielded by radiography, which

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* Research Laboratory, General Electric Company, Schenectady, N. Y.

does not alter the sample. Probing can reveal interior attack but in most cases cannot define the shape of pits.

Photographs and Radiographs Compared. A glance at almost any of the radiographs in this article will show features that might well have escaped photography or visual observation. To emphasize this point, a few comments will be made below on the salient features of the sets of parallel radiographs and photographs given in the first four figures. The two sides of each specimen were nearly enough the same so that it was unnecessary to photograph both.

Figure 1. Type 302. 1) The radiograph shows edge attack to be more pronounced than the photograph indicates. 2) Only the radiograph shows the true extent to which metal has been removed. Notice that the surface of the specimen appears unbroken except for a few isolated patches. Corrosion has gone far enough, however, so that light is transmitted by some of the apparently unbroken patches. 3) The radiograph alone reveals the characteristic "pine tree" form of the pits.

Figure 2. Type 302. When compared with Figure 1 it is obvious from the radiograph, but not from the photograph, that rotation has modified the shape of the pits.

Figure 3. Type 347. 1) The radiograph shows that the elongated, triangular pits are much more numerous than the striations in the photograph. This suggests that the striations occur only when interior attack has gone far enough so that the walls of the pits become depressed before the photograph is made. 2) The radiograph shows pits at all stages of development in the area under the polystyrene holder. In the original print these pits are whitest in the bottom section, and become darker (because less metal has been removed) toward the center. Their elongated form persists, and this indicates that corrosion proceeds most readily in the direction of rolling. 3) At the upper edge of the sample the radiograph shows diffuse areas of attack at the boundary of the holder. Over these areas, where the holder was closest to the sample, metal had been removed by external attack.

Figure 4. Type 317. 1) Both photograph and radiograph show that the sample has suffered marked edge attack. 2) Only the radiograph gives evidence of the attack that has occurred in oval areas away from the edges. Most of these ovals are underneath the polystyrene holder, and their long axes are perpendicular to the axis of rotation. 3) This radiograph also shows diffuse areas of attack near the top, similar to those in Figure 3.

Effect of Chemical Composition. Comparison of Figures 1 and 5 shows that edge attack and pitting are quite similar for Types 302 and 347 on annealed samples. Annealed Type 317 shows a little edge attack but no pitting.

Effect of Cold Deformation. Bars of Type 347 and 317 stock were reduced 90 percent in thickness by rolling to make the 25-mil strip that was used to show the effect of cold deformation on attack by ferric chloride. The annealed samples of Figure 5 were prepared by heating squares of the rolled strip for 20 minutes in hydrogen at 2000 degrees F, quenching in water and pickling in hydrofluoric-nitric acid mixture. Photomicrographs of rolled specimens showed

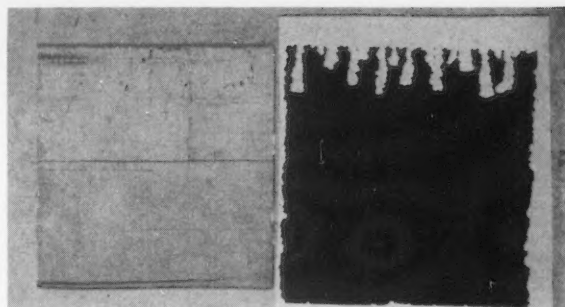


Figure 1—Photograph (left) and radiograph (right) of annealed Type 302 square after 2-day stagnant immersion in the ferric chloride solution. Note the white "pine trees" in the radiograph. In these white areas, metal has been almost completely removed from the interior of the specimen.

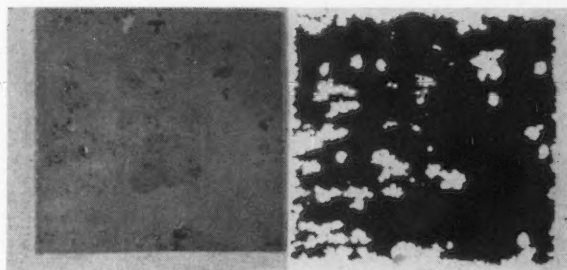


Figure 2—Parallel photograph and radiograph for annealed Type 302 square after 2-day rotation in the ferric chloride solution. Axis of rotation vertical.

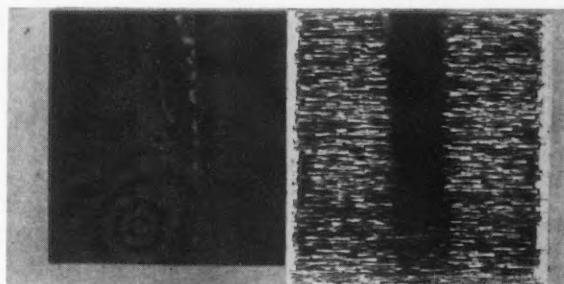


Figure 3—Parallel photograph and radiograph for rolled Type 347 square (not annealed) rotated as for Figure 2. The rolling direction is perpendicular to the axis of rotation, and the upper edge of the specimen (as shown above) was nearest the top.

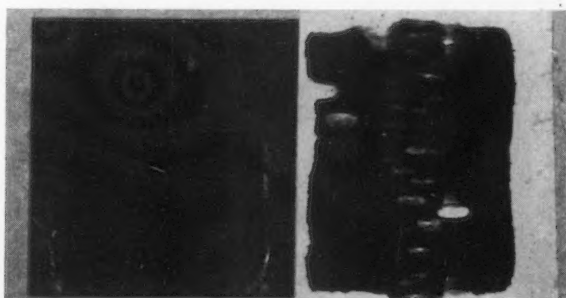


Figure 4—Parallel photograph and radiograph for rolled Type 317 square (not annealed). Experimental conditions as in Figure 3.

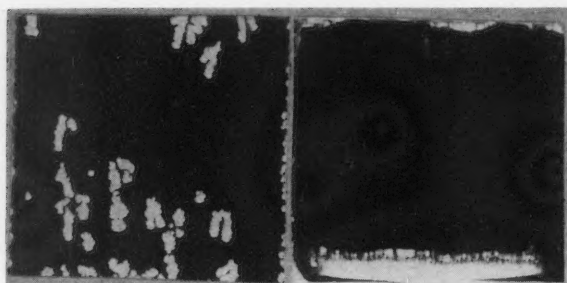


Figure 5—Radiographs of annealed squares of Type 347 (left) and Type 317 (right) after 2-day stagnant immersion in the ferric chloride. Compare with radiograph in Figure 1.

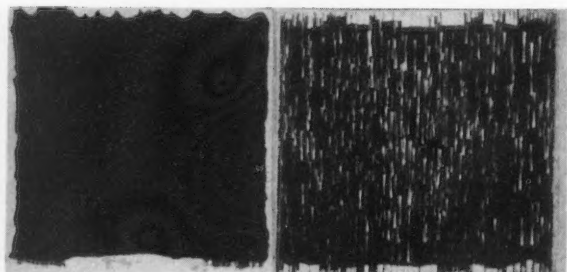


Figure 6—Radiographs showing the effect of cold deformation on the corrosion of Type 317 (left) and Type 347 (right) by the ferric chloride solution. The rolling direction is vertical for the radiographs and was vertical also for the 2-day stagnant immersion.

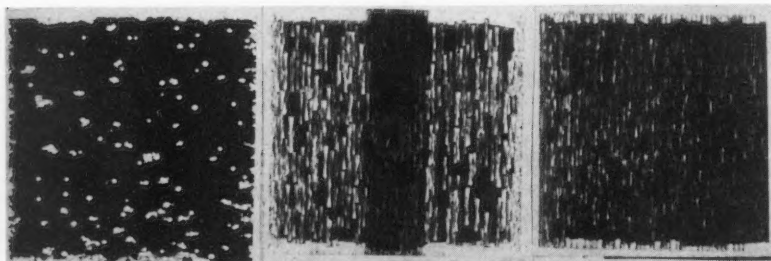


Figure 7—(Begin at left.) 1) Radiograph showing effect of immersing Type 302 steel horizontally in ferric chloride solution. Compare with radiograph in Figure 1. 2) Radiograph showing absence of directional effect of rotation on corrosion pattern in steel of Figure 3. The sample was rotated for two days in ferric chloride solution with rolling direction coinciding with axis of rotation. 3) Absence of gravitational effect on corrosion pattern in steel of Figure 3. The sample had vertical stagnant immersion for one day with rolling direction horizontal.

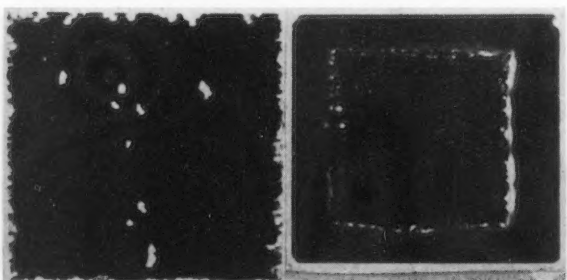


Figure 8—1) Radiograph showing reduced corrosive effect of spent ferric chloride solution, 2) Radiograph showing effect of paraffining edges of Type 302.

lines of inclusions in the direction of rolling for both kinds of steel, which could be taken as evidence of considerable cold deformation during rolling. Annealed specimens of both kinds showed normal grain structure.

Comparison of the Type 317 radiographs in Figures 5 and 6 shows no marked differences, although edge attack has been more severe on the unannealed specimen. This edge attack is approximately uniform along the periphery.

Comparison of the Type 347 radiographs in Figures 5 and 6 shows that cold deformation of this metal causes deep-seated changes in its behavior toward ferric chloride solution. These changes may be summarized as follows: 1) The number of pits is multiplied. 2) The shape of the pits is changed. 3) The pits are oriented in the direction of rolling. (Evidence will be presented later to show that gravitational forces have little effect on this corrosion pattern.) 4) Edge attack is marked in the direction of rolling and absent in the other direction.

Cold deformation lengthens the grains and it may be that the concomitant strains cause the Type 347 steel to be more readily attacked in the direction of rolling. We have no explanation for the triangular form of the pits, nor of the fact that the triangles point both up and down. Probably so many of the vertices of these triangles seem to touch because the oppositely oriented pits meet as the pits grow. It must be remembered that these pits may not all be in the same plane and that their growth was no doubt influenced by inclusions oriented in the direction of rolling.

Effect of Gravitational Forces. In 1938, Type 302 squares were suspended in ferric chloride solution from a hole in one corner. The "pine trees" then obtained were larger than those in Figure 1 and were oriented parallel to the direction of gravity. The effect of gravity was then assumed as being

due to a tendency to reduce the mixing within the pits of the dense solution of corrosion products, which eventually find their way out.

In 1940, Uhlig¹ published an extensive discussion of the effect of gravity on pitting of stainless steel under different conditions. As a consequence of his work, additional experiments were carried out in 1949 by the authors. Some of the results are given here to illustrate the value of radiography.

The simplest experiment was the horizontal immersion of a Type 302 plate in the ferric chloride solution. The radiograph (Figure 7) shows numerous pits, small, round and evenly distributed. Obviously, if the gravitational field acts to promote downward growth of the pits in Type 302, then no pit can grow downward more than 25 mils through the horizontal plate, 25 mils being the thickness. Again, if gravity has this effect, there should be little lateral growth of pits in the horizontal plate. The experiment thus confirms the assumed gravitational effect. The much

greater number of pits here as compared with vertical immersion (Figure 1) may be due mainly to the fact that the lower part of the specimen in the latter case is soon bathed by spent solution.

Rotation of the sample provides the analogue of a gravitational field in the direction perpendicular to the axis of rotation. (The maximum centrifugal acceleration due to the rotation was about 0.2 times that of gravity.) Consequently, the pits in Type 302 should be distorted in this direction when the sample is rotated. The radiograph in Figure 2 shows that this tends to occur. The same conclusion may be valid for the radiograph of Figure 4. It must be remembered that the solution outside the pits is mixed completely during rotation, but not during stagnant immersion.

There appears to be no measurable effect of the gravitational field on the corrosion pattern for rolled, unannealed Type 347, perhaps because the pits are small and because the directional effect due to cold deformation is too pronounced. This conclusion is based on a comparison of radiographs in Figures 3, 6 and 7. Detailed discussion seems unnecessary, but it will be pointed out that rotation increased the width of the pits when the rolling direction coincided with the axis of rotation; and that rotation produced offsets at the top and bottom of the rotated specimen in Figure 7. (There are no offsets in the corresponding radiograph of Figure 3.)

Crevice Corrosion. The radiographs in Figures 2, 3 and 4 give evidence of an interesting variation of the corrosion that occurred in the crevice between the sample and the polystyrene holder. In Figure 2,

the area under the holder shows the normal amount of corrosion; in Figure 3, much less; in Figure 4, much more. Perhaps the large number of pits in the rest of the specimen provided a measure of cathodic protection for the area under the rod in Figure 3. There would be virtually no such protection in the case of Type 317, because there is little or no pitting in the areas adjacent to the holder.

Miscellaneous. A series of radiographs (not included herein) showed that corrosion progressed quite slowly after the first two days' immersion of rolled Type 347 steel. Another radiograph (not included herein) proved that pickling in mixed hydrofluoric-nitric acid solution had the expected effect in reducing the extent of attack by ferric chloride.

The sample in Figure 8 1) is annealed Type 302 after exposure for two days in stagnant ferric chloride solution that had been used in a previous two-day exposure of Type 302. When this is compared with Figure 1, the reduced corrosive action of the spent ferric chloride becomes obvious.

Figure 8 2) illustrates how paraffin on the edges of a Type 302 sample may greatly reduce the edge attack but may not be completely successful, especially at the corners. Moreover, the paraffin may lead to crevice corrosion where the paraffin coating stops.

Acknowledgment

T. Stack, Schenectady Works Laboratory, is thanked for making contact radiographs shown herein.

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Discussions

Graphical Multiple Correlation of Corrosion Data. By O. B. Ellis. *CORROSION*, Vol. 8, No. 6, 203-208 (1953) June.

Question by Hugh P. Godard, Aluminium Laboratories, Ltd., Kingston, Ont., Canada:

The simplicity of the graphical correlation method is extremely attractive and I am sure that it will find extensive use in treating corrosion data. I would like to ask what happens if you overlook an important variable in plotting the curves. How does this omission show itself?

Reply by O. B. Ellis:

If an important variable is overlooked, a relatively poor correlation will be obtained. This will be evident in the early work by failure of successive plots to reduce the deviations of the points from the estimated lines. If the omitted important variable is added later, an improvement in the deviations will be noticed almost immediately.

Discussion by F. C. Jelen, Solvay Process Div., Allied Chemical & Dye Corp., Syracuse, N. Y.:

This was an excellent paper. It should be realized that in any mathematical analysis of this type some judgment must be used in interpretation and application. In the illustration given by Mr. Ellis the effect associated with each constituent follows a smooth curve. Sometimes a critical concentration for one constituent is involved and Mr. Ellis' method would detect this only if tests were made above and below the critical concentration. If more than one constituent has a critical concentration, or worse if a critical concentration of one constituent varies with the concentration of other constituents, the graphical method might be inconclusive. The graphical or mathematical analysis can be dependent in utility upon the judgment used in selecting the variables. For example, in the susceptibility to intergranular corrosion of stainless steel the important variable is the product of columbium times carbon, the concentrations of columbium or carbon individually are much less important. In general the graphical method will be less conclusive as the variables are less independent.

Question by E. W. Wallace, 5304 Huisache, Bellaire, Texas:

I gather that the graphical method is applicable to correlation of data where the effects of the variables are additive. Could you also say if the method applies to data where the effects of the variables are multiplicative—as, for example, the effects of alloys on the hardenability of steels?

Reply by O. B. Ellis:

I have had no experience with data of the type referred to in the above question. However, it is suggested that, if it is known that the effects of variables are products or ratios, the difficulty of the problem could be reduced by plotting the logarithms of the variables.

Questions by John Leroy Horton, Box 360, Natchez, Miss.:

1. What is the text on this subject?
2. Can a final equation be arrived at graphically?
3. What type of equation will result if one variable has no effect?

Replies by O. B. Ellis:

1. A text devoted to development and discussion of the graphical method of multiple correlation is not known. The work by Mordecai Ezekiel, referred to in the paper, contains the best references which were available to the author.

2. It is possible to derive an equation from the final curves developed by the graphical method. This can be done by measuring the slopes of the final lines and setting up an equation with the coefficients of the variables equal to the slope. However, if one has developed the proper relationships graphically, there seems to be little additional information that can be gained by deriving an equation.

3. If a variable has no effect, its coefficient in an equation would be zero.

All-Plastic Materials of Construction for Corrosive Environments. By J. L. Huscher. *CORROSION*, Vol. 9, No. 8, 272-276 (1953) Aug.

Discussion by L. B. Kuhn, Firestone Plastics, Pottstown, Pa.:

I agree with Mr. Prange in that data on creep of plastic materials must be included in any consideration of their basic engineering characteristics. Unfortunately, at the present time, there is little of this data available. Our laboratories at Firestone are currently engaged in obtaining complete data on the creep characteristics of unplasticized polyvinyl chloride based on Exon 402A resin. These data are not yet complete, however, and it is not possible to forecast a completion date because of the inherently slow nature of the test methods being employed. When these data do become available, it will be published along with the chemical, electrical and other mechanical characteristics of unplasticized polyvinyl chloride. I am certain that other laboratories of both raw materials suppliers and potential users of unplasticized

polyvinyl chloride and other plastics are working along similar lines and recommend that any potential user stay in contact with his raw material supplier with reference to data required until they become common engineering knowledge.

Discussion by W. M. Ruddock, Carlon Pipe Division, Beardmore & Co., Ltd., Toronto, Canada:

Some of the discussion has been concerned with the apparently misleading information published by many manufacturers of the various types of plastic pipe, regarding tensile strength. This misunderstanding probably arises from the fact that a great many manufacturers of plastic pipe quote an ultimate tensile strength which is far in excess of the

yield point. Our company now emphasize the "Effective Tensile Strength" or that point where the pipe just commences to expand under pressure. An example of this is in connection with the rigid pipe, designed primarily for the oil industry, which is designated as Type L. Recent U. S. Navy tests established that this material has an effective tensile strength of 3500 psi at 77° F. It is possible to obtain an ultimate tensile strength of as high as 6000 psi on this material, depending on the duration of the tension test. Our working pressures are based on a 3 to 1 factor of safety, calculated from the effective tensile strength. This we feel is in accordance with sound engineering practice.

NACE Practice on Reprinting Technical Material

Requests for prices on reprinting material appearing in CORROSION should be addressed to National Association of Corrosion Engineers, 1061 M & M Building, Houston 2, Texas. Prices usually cannot be given until after articles have appeared in CORROSION although requests for prices may be submitted at any time. Type from which technical articles are printed is kept standing for 90 days after date of issue, and reprints ordered during that interval will be from standing type. For reprints ordered after expiration of this period, write for details. Single copies of reprints of material from CORROSION are listed in advertisements appearing in

many issues. Usually single copies may be obtained only in the form of tear sheets, or whole copies of the issue in which the article appears.

Permission to reprint articles usually is given to responsible firms and individuals who wish to have the work done themselves. NACE requires, however, that proper credit be given CORROSION at an appropriate place on all reprint material. The association also requests that reprint style closely conform to that approved by its board to be in keeping with the aims and objectives of the association and that copies of reprints made under this authority are supplied NACE for recording purposes.

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October
1952—March

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Index to Vol. 6, 1950 December, 1950
Index to Vol. 7 December, 1951
Index to Volume 8 December, 1952

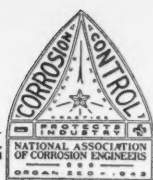
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TEXAS



Topic of the Month

Some Corrosion Hazards From DC Welding Currents

By H. W. WAHLQUIST*

ON LARGE CONSTRUCTION projects such as refineries, power stations, or industrial plants where extensive dc welding operations are involved on underground piping networks, serious corrosion may occur on the piping during construction if the ground connections on welding machines permit substantial currents to flow in the earth. During the initial stages of construction when the piping systems are not metallurgically interconnected, welding performed on one structure, using a ground connection on another structure, results in heavy current discharge to earth on one of the structures, depending on whether straight or reverse-polarity welding is used. If the electrode is negative, as in straight polarity, the corrosion occurs on the structure used as a ground; with reverse polarity the structure being welded will corrode.

Figure 1 illustrates the current flow with straight-polarity welding on two underground piping systems not metallurgically interconnected, with corrosion taking place on the pipe used as a ground. Where the piping is bare, the current discharge is usually distributed over considerable area and the overall damage to the piping is small. However, where the pipe used as a ground is coated, the high current densities at holidays or damaged spots on the coating may result in severe pitting at these points. Coated pipe several thousand feet in length in low-resistivity soils will often have suffi-

ciently low resistance-to-earth to satisfy the welding operation and the practice of striking an arc to check for the adequacy of the ground does not show whether or not metallic continuity exists. In one situation, welding operations during construction caused complete penetration of the pipe wall at points where the coating was damaged.

With the welding machine connected as in Figure 2, the welding currents flow in a metallic circuit and no corrosion of the piping results.

Figure 3 illustrates a frequent source of corrosion from dc welding operations on two or more structures, using a common dc source. A large generator located on shore supplies a dc bus for welding on ships. If a poor contact exists between the positive bus and Ship "B," the welding currents on Ship "B" will discharge from Ship "A" causing rapid destruction of the paint and severe pitting on Ship "A."

In Figure 4 the positive grounding connections are welded to the ship to insure perfect connections. This greatly reduces corrosion currents but does not completely eliminate them. Assume for example that welding operations are in progress on Ship "A" only, as illustrated in Figure 5. The IR drop in the positive feeder from the generator to Ship "A" causes current to discharge from Ship "B" and collect on Ship "A" due to the parallel path provided by the sea water. When it is considered that the resistance-to-earth of a ship in sea water may range from a few hundredths to only one thousandth of an ohm, it is evident that large dc bus conductors must be provided in situations of this type to minimize corrosion from stray currents.

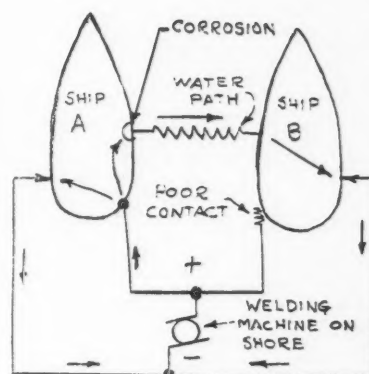


Figure 5

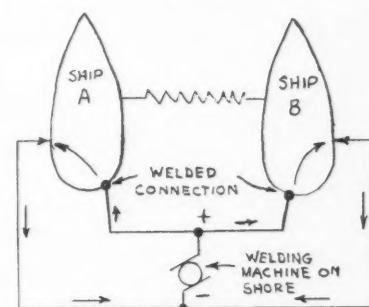


Figure 4

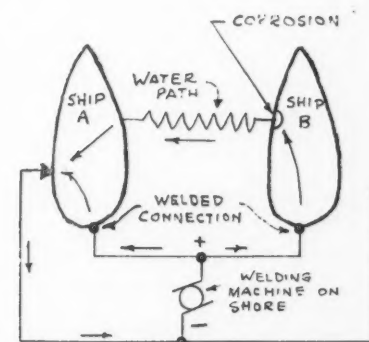


Figure 3

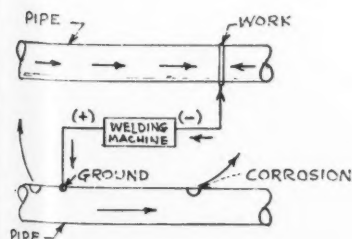


Figure 1

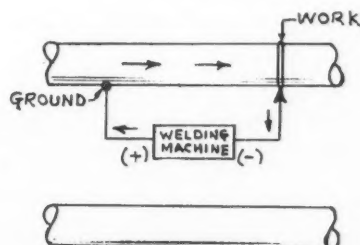
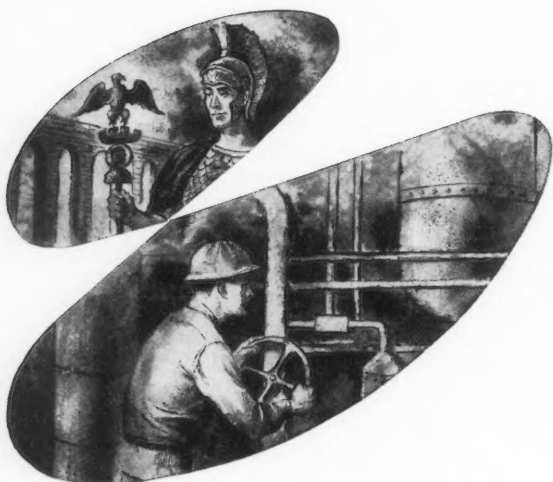


Figure 2

*Electrical Engineer, Ebasco Services, Inc., New York, N. Y.



REGISTRANTS AT TEXAS A & M SHORT COURSE—Persons who registered for the short course on corrosion held at Texas A & M College in September are shown here.



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Registrants From Nine States Attend Short Course at A & M College

Registration for the Corrosion Short Course held September 22-25 at Texas A & M College, College Station, was 122, including instructors. Registrants came from nine states and Canada, although the great majority were from Texas. The 4-day course, first held on corrosion at the school, was held with the cooperation of South Central Region, National Association of Corrosion Engineers.

The program covered fundamentals of corrosion, with sessions on various aspects, including materials, environment, metals, coatings, cathodic protection instruments and four "special topics": Organization of Corrosion Departments, by H. L. Bilhartz, Atlantic Refining Co., Dallas; Corrosion Inhibitors, by Floyd Blount, Magnolia Petroleum Co., Dallas; Sea Water as an Industrial Coolant—Materials of Construction and Corrosion Problems by William B. Brooks, Dow Chemical Company, Freeport and Corrosion by Fresh Water, by Charles P. Dillon, Carbide & Carbon Chemicals Co., Texas City.

So-called "Bull Sessions" scheduled for September 23 lasted well past 11 pm, evidence of the high degree of interest in the course.

Success of the course was such there was an indication Texas A & M may be planning to hold another similar course next year.

Oklahoma U. Course Scheduled Dec. 1-4

Registration for the Corrosion Control Short Course to be given at Norman by University of Oklahoma, December 1-4 is \$15. A dinner is scheduled for December 3, tickets for which are \$2.50. The course will consist of technical papers and panel discussions by the College of Engineering and the Extension Division of the University in cooperation with Central Oklahoma Section of NACE. John P. Roberts, professor of metallurgy, will direct the course.

Rooms may be reserved at the Extension Study Center Dormitory at \$1.50 and \$1.75 per person and family accommodations are available at nearby hotels and auto courts. Breakfast and lunch are available at the Extension Study Center Cafeteria.

Registrations should be addressed to: John B. Freeman, Director, Dept. of Short Courses and Conferences, University of Oklahoma, Norman.

Abstracts of Indian Institute to Be Carried

Abstracts from articles published in the Transactions of the Indian Institute of Metals, Calcutta, will be included in the Corrosion Abstract Section of CORROSION magazine and will be used in other abstracting services of NACE. The code designating these abstracts will be "IIM."

Of the editorial material published in CORROSION in 1952, 77 percent was of reference value.



NACE News

Bulow Addresses Philadelphia Section

C. J. Bulow, Corrosion Metallurgist, Bridgeport Brass Co., Bridgeport, Conn., spoke to 125 NACE and ASTM members and guests at a September 18 meeting of Philadelphia Section. It was the first joint meeting of NACE and the American Society for Testing Materials in Philadelphia.

Speaking on Copper and Copper Alloys, Mr. Bulow described them from the standpoint of corrosion resistance, physical and mechanical properties and fabrication properties. Influence of alloys, corrosive media, temperature, stress, inhibitors, cleanliness and other factors were covered.

Mr. Bulow, in addition to being on ASTM's Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys and NACE TP-5 on Corrosion Problems Involved in Processing and Handling Chemicals is a member of the American Chemical Society, Electrochemical Society, Non-Ferrous Sub-Committee of the ASME Boiler Code Committee, American Petroleum Institute and Institute of Metals.

Guests at the meeting included George Herman and Victor Sweet, seniors majoring in metallurgical engineering at the University of Pennsylvania and recipients of the Warwick Memorial Award at the university.

Five panel members have been named for a round table discussion meeting scheduled October 23 at the Poor Richard Club by Philadelphia Section. R. R. Pierce of Pennsylvania Salt Manufacturing Co., will be moderator, with the following panel members:

Cathodic protection, M. C. Miller, Ebasco Services, Inc.

Metals, Ward R. Meyers, E. I. duPont de Nemours & Co., Inc.

Protective coatings, Kenneth Tator, Corapolis, Pa., or J. H. Cogshall, Pennsylvania Salt Manufacturing Co.

General corrosion problems, W. L. Burton, Allied Chemical & Dye Corp.

Whitney Is Speaker At New York Session

Frank L. Whitney, Jr., Monsanto Chemical Company, St. Louis, was the speaker for the technical portion of the program at the September 23 meeting of the Metropolitan New York Section. Mr. Whitney gave a paper entitled Case Histories Illustrating Methods of Combating Corrosion. The paper covered three methods of mitigating corrosion; inhibition, cathodic protection and process change. The latter embraced field problems in which changes of concentration, temperature, chemicals and operation minimize corrosion. There were 110 members and guests present.

In 1952, for every page of advertising published in CORROSION two pages of editorial matter were published.



NACE MEETINGS CALENDAR

Nov.

9—Greater St. Louis Section. Corrosion Problems in Ion Exchange Systems by J. F. Wilkes.

9—North Texas Section. Unusual Applications of Cathodic Protection by Cecil Smith.

Dec.

1—Baltimore Section.

2—Southern New England Section.

4—Greater Boston Section. Use of Inhibitors in Water Treatment (Tentative).

REGIONAL MEETINGS

Nov.

12—South East Region, Birmingham, Ala.

19-20—Western Region, Biltmore Hotel, Los Angeles.

Kanawha Valley Section Discussion Is Held

Twenty-four members and five guests participated in a round table session of Kanawha Valley Section Sept. 17. The meeting was held at Hotel Pritchard in Huntington, W. Va. and was moderated by J. M. Bates.

Among the things discussed were corrosion of Admiralty metal and 304 SS condensers, using Ohio River water as the cooling medium, corrosion resistant material for use with various combinations of benzene, monochlorobenzene, phenol and hydrochloric acid at temperatures up to 100 degrees C. Preferred treatments for pump bases subject to acid and organic spills was discussed by A. W. Horne, Plant Engineer, The Bakelite Company.

Aluminum tubing and nickel plating of tube sheets of condensers were discussed also.

Chicago Section's Ladies' Night Well Attended

Between 85 and 100 were present for the September 15 Ladies' Night meeting of Chicago Section to enjoy a fellowship hour and dinner. Spring Packing Corporation was host at the meeting.

L. W. Ewing, of Standard Oil Company of Indiana, section chairman, introduced new officers and section committee heads.

"The duPont Story," a color motion picture, was shown.

The section is scheduled to meet next October 20 to hear Ellis D. Verink of Aluminum Company of America discuss "Use of Aluminum in the Chemical and Petrochemical Industries."

Edmonton Section Is Being Organized

The Canadian Regional Division has announced that a new local section is being organized in Edmonton, Alberta. Mr. F. W. Hewes, Canadian Protective Coating, Limited is acting as interim chairman of the section and doing a great deal of the organizational work necessary to forming a section. The Edmonton Section will hold its initial meeting in November at which information about NACE and technical programs will be presented. The second meeting will be held as soon as the board of trustees of the Canadian Region has approved the Edmonton Section petition for recognition.

British Columbia Section Renamed Vancouver

The name of the British Columbia Section of the Canadian Regional Division has been changed to Vancouver Section. The name was changed with the thought that there may be other local NACE Sections organized in British Columbia in the future. The executive committee of NACE has passed a resolution that no local NACE Section shall have the name of a state.

Greater St. Louis Section Plans Future Meetings

Three subjects for future meetings of Greater St. Louis Section have been given as follows:

Nov. 9—Corrosion Problems in Ion Exchange Systems by J. F. Wilkes, Dearborn Chemical Co., Chicago.

Dec. 14—Corrosion in Action, International Nickel Co., Inc., motion picture.

Jan. 21—Weld Seam Corrosion and Its Control by A. J. Liebman, Dravo Corp., Pittsburgh.

Scheduled for the October 12 meeting was "Prevention of Hydrogen Attack on Steel in Refinery Equipment," by W. A. Bonner, Shell Oil Co., Wood River, Ill.

Raymond B. Seymour, technical director of Atlas Mineral Products Co., Mertztown, Pa., spoke to 45 members and guests of the section at a dinner meeting September 14. His subject was "The Role of Plastics in Corrosion Protection." He was assisted in the presentation by E. Erich and G. Shutt, both of Atlas Mineral Products Co.

New officers for 1953-54 were introduced as follows at this meeting: C. A. Coberly, chairman; W. J. Ries, vice-chairman; R. D. Sanford, secretary and D. H. Becker, treasurer. Board members: F. L. Whitney, Jr., W. E. Kleefisch, H. O. Nordquist, C. A. Butts and G. A. Fisher, Jr.

CORROSION has 680 readers in foreign countries.

Four Papers, Plant Tour Set for South East Region's Meeting

Four papers, a round table discussion of the papers presented and a plant tour are scheduled November 12 on the program for the meeting of South East Region at Birmingham, Ala.

Papers will be given by R. B. Hoxeng, U. S. Steel Corp., Pittsburgh, "Fundamentals of Corrosion"; W. F. Fair, Jr., Koppers Company, subject to be announced; J. F. Tatum, Willmut Gas & Oil Co., "Cathodic Protection"; Arthur Smith, Amercoat Corp., "Latest Developments in the Vinyl Field." Herbert Van Nieuhuys, Southwestern Pipe Line Co., will be moderator for a joint discussion of the papers. In the afternoon a tour of the United States Steel Corporation plant in Birmingham is scheduled.

Lakeland, Fla. Session Features Papers, Movies

Papers were presented and motion pictures on corrosion subjects were shown at the October 2 Florida South-eastern College, Lakeland, Fla. meeting of Jacksonville Section. This was the third meeting of the recently-organized section. The evening sessions consisted of a dinner and a short talk by A. B. Campbell, NACE executive secretary on the relationship between NACE and the region and section organization and on other functions and activities of the association.

Talk on Stainless Steels Featured at Meeting Of Boston Section

John J. Halbig, Corrosion Engineer, Armco Steel Corp., Middletown, Ohio, was the speaker scheduled to address Greater Boston Section NACE at an October 14 meeting at Brookline. His subject was announced at "Performance of Stainless Steels in Corrosive Environments."

Tentatively scheduled for the section's December 4 meeting was the topic "Use of Inhibitors in Water Treatment."

Planning for the year by Greater Boston Section includes meetings for the first Wednesdays in December, February and May. The latter two meetings are expected to program topics on protective coatings and reducing corrosion by design respectively.

The special activities committee is considering the feasibility of organizing an educational program in corrosion and a family vacation trip to the Inco Kure Beach test station in North Carolina next year. Plans also are under way to increase the present section membership of 87 to over 100 before year's end.

Committees organized in the section are as follows: Program: E. C. Ruse, chairman; Murray Jacobson, W. H. Keller, L. H. Perry, Milton Stern and E. O. Smith. Reception and Publicity: H. M. Kelley, chairman; H. W. Reinhardt, C. L. Goodwin, H. S. Miller and C. L. Prescott. Arrangements: C. G. Brown, chairman; O. W. Robinson,

J. W. Stanley, John Hancock, D. J. Allia. Membership: Minot Shaw, chairman; B. F. Barnwall, J. B. Judge, E. A. Turner, James Duggan. Special Activities: Daniel Cushing, chairman; Manson Glover.

Seymour Talks Before Group at Reading

A discussion of plastics for the chemical industry was the scheduled topic of a talk October 27 by Raymond B. Seymour, director of research for The Atlas Mineral Products Company before the Southwestern Ohio Section. The dinner meeting was planned for Shuller's Restaurant, Reading, Ohio.

Lively Discussion Held At Meeting in Dallas

Lively discussions featured the September 21 meeting of North Texas Section at Venus Restaurant, Dallas. B. B. Morton, of the Corrosion Engineering Section, The International Nickel Co., Inc., New York, spoke to 32 members and four guests on "Some Moot Corrosion Problems." His remarks, featured by his lively wit and extensive corrosion experience, covered pro and con considerations on ten situations likely to face the corrosion engineer.

J. C. Spalding, chairman named as a nominating committee for next year's officers as follows: Morris Bock, H. E. Bilhartz and himself.

FEDERATED METALS OFFERS NEW REPORT: "CATHODIC PROTECTION WITH ZINC ANODES"

Federated's Corrosion Advisory Service offers you, without obligation, a new report titled, "Cathodic Protection With Zinc Anodes," prepared by Ebasco Services Inc. for the American Zinc Institute. This new publication reports additional findings obtained since the first report was issued in November, 1951. In it you will find important and valuable facts that have influence on the proper applications of zinc anodes. Use coupon below for your free copy.

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North Texas Section Schedules 4 Meetings

Four meetings have been scheduled as follows by Dallas Section:

October 19 — Cattleman's Cafe, Ft. Worth. Tom Newell, Cardinal Chemical Co., on Mechanics of Corrosion Inhibitors.

November 9—Dallas. Cecil Smith, Carter Oil Co., on Unusual Applications of Cathodic Protection.

December 7—Place undetermined. Dave Levy, Magnolia Pipe Line Co., on Management and the Corrosion Engineer.

January 4—Place not determined. R. R. Crowder, Dallas Power & Light Co., on Cooling Water Problems.

Sabine-Neches Section Discusses Inhibitors

J. A. Rippetoe, Jr., of Pure Oil Company's Smith's Bluff Refinery talked on "The Use of Organic Inhibitors in Refinery Corrosion Control" before 30 members and 11 guests at the September 24 dinner meeting of Sabine-Neches Section. A discussion period following Mr. Rippetoe's talk evoked interesting comment from several guests. These guests, representing Socony-Vacuum's refineries at Augusta, Kan., Providence, R. I., and East Chicago, Ind., had been attending a Socony-Vacuum corrosion meeting in Beaumont. They related experiences with inhibitors and contributed much to the meeting. Representatives from 10 refineries were present.

Vinyl Plastisols Is Topic At Los Angeles Meeting

Technical aspects of vinyl plastisols were discussed by C. I. Spessard of Bakelite Company and Allyn E. Webb of Barber-Webb Company before 67 members and guests of Los Angeles Section. The dinner meeting was held September 19.

Mr. Spessard said plastisols fall into two classes: Organisols, which are vinyls suspended in an organic solvent and hydrosols, which are vinyls suspended in water. Both materials are set by heat. In compounding, Mr. Spessard pointed out, important factors are particle size, usually between 0.05 and 1.3 microns and the viscosity of the mixture. These must be controlled closely to provide the right properties for each application.

Thinners, fillers and plasticizers all affect viscosity. These materials may be applied by spraying, dipping, brushing and other methods. Finished films usually have a tensile strength of 4000 to 5000 psi after baking.

Mr. Webb, commenting on application of plastisols, said vinyl plastics have high resistance to many acids and bases and will retain desirable properties if sustained temperatures are below 180 degrees F and short time highs of 300 degrees F are maintained. High temperature causes evaporation of plasticizers and hardening and cracking of the vinyl, he said. Effectively coated with plastisols are fume ducts, fans and plating equipment, Mr. Webb said.

Fresh Water Corrosion Is Topic at Lake Charles

Corrosion by Fresh Water was the scheduled topic of discussion by Charles P. Dillon, Carbide & Carbon Chemicals Company, Texas City, before members of Sabine-Neches Section October 22. The dinner meeting was planned for Lake Charles. Mr. Dillon is chairman of NACE TP-8A on Corrosion by Gulf Coast Cooling Waters.

Corpus Christi Barbecue

The annual barbecue of Corpus Christi Section was held for members and their families September 26 at Humble's Flour Bluff Camp picnic grounds near Corpus Christi. There was no technical or business meeting.

Inter Society Committee CORROSION MEETINGS CALENDAR

Nov.

12—61st Annual Meeting, Society of Naval Architects and Marine Engineers, Waldorf-Astoria Hotel, New York City. Electrolytic Corrosion Inhibiting and Cleaning With Energized Electrodes by H. F. Harvey, Jr., and H. O. Streever, 2 p.m.

ASTE Exposition

The 10th Biennial American Society of Tool Engineers' Industrial Exposition will be held April 26-30 at Philadelphia.

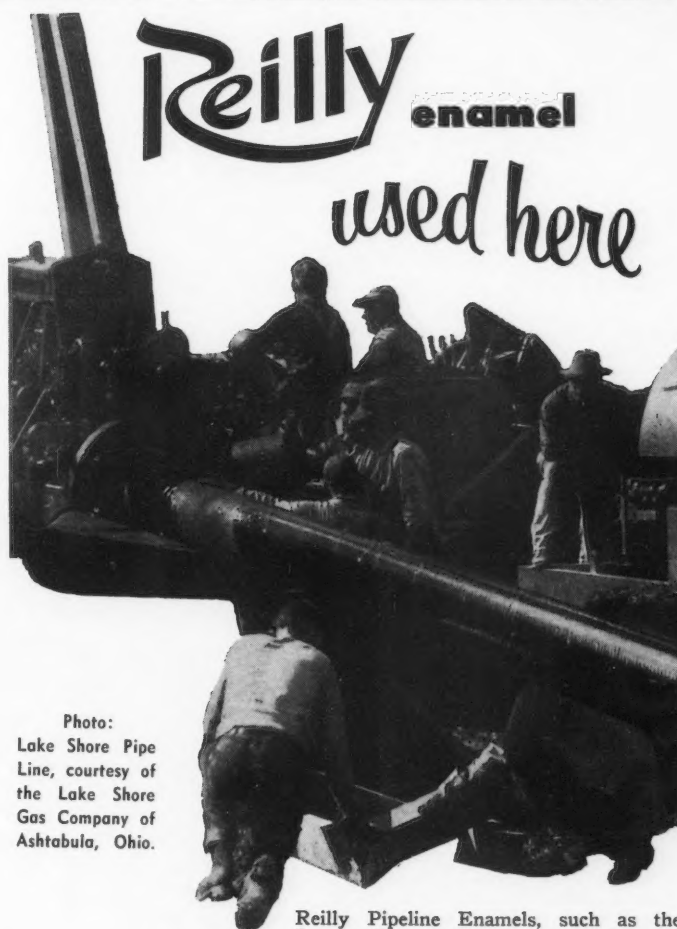


Photo:
Lake Shore Pipe
Line, courtesy of
the Lake Shore
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Western Region's Nov. 19-20 Program Outlined

Following is the schedule for the Western Regional Division Conference program:

November 19

9 a.m. to noon, registration.
9:30 to 10:45 a.m.—Technical Practices Committee meetings: TP-1A on Corrosion of Oil and Gas Well Equipment, Renaissance Room, Frank Davie, chairman. TP-6L on Asphalt Type Underground Protective Coatings, Conference Room 8, R. J. Schmidt, chairman. Open to members and guests.

Morning Technical Session, E. H. Grizzard, chairman.

11:00 a.m.—Selling Management on Corrosion Control, H. H. Anderson, Trans Mountain Pipe Line Co.

Noon—luncheon.

Afternoon Technical Session, Robert H. Kerr, chairman.

2 p.m.—Corrosion Prevention and the Gas Industry's New Safety Code, F. A. Hough, Southern Counties Gas Company of California.

2:45 p.m.—Plastic Tape as Corrosion Control Coating, Howard D. Segool, Polyken Products Dept.

3:30 p.m.—Factors Affecting the Corrosion of Aluminum Pipe Used in Sprinkler Irrigation, Mark F. Adams, State College of Washington.

General Business Meeting.

5:30 p.m.—Fellowship hour.

November 20

Morning Technical Session, Austin S. Joy, chairman.

9:30 a.m.—The New Look in Air Transport Maintenance, J. S. Farra, Douglas Aircraft Co., Inc.

10:15 a.m.—Control of Stress-Corrosion Cracking, R. N. Hooker and Joseph L. Waisman, Douglas Aircraft Company, Inc.

11 a.m.—Ceramic Coating Developments and Uses, John V. Long, Solar Aircraft Company.

Noon—luncheon.

Afternoon Technical Session, Larry L. Whiteneck, chairman.

2 p.m.—Some Observations on Corrosion in the Oil Industry by R. S. Crog, Union Oil Company of California.

2:45 p.m.—The Use of Organic Inhibitors in Refinery Distillation Process Equipment, G. E. Purdy, Tretolite Co.

3 p.m.—Review of Corrosion Resistant Materials in Refinery Service, B. B. Morton, The International Nickel Co., Inc.

Committees

Program: Vance N. Jenkins, chairman; M. L. Michaud.

Publicity: F. Travers Wood, Jr., chairman; David J. Colyer, Jr.

Financial: Robert H. Savage, chairman; Walter H. Cates.

Membership: Fred M. McConnell, chairman; Albert G. Zima.

Registration: Hugh F. Flynn, chairman; James G. Kerr.

Facility-Arrangements: Dean E. Stephan, chairman; Joseph W. Coffey.

Hospitality: K. T. Vangsnes, chairman; W. D. McSparran, John G. McComas, co-chairmen.

AUTHORS & ABSTRACTS

Western Region Program

Ten technical papers are scheduled for the Third Annual NACE Western Region meeting to be held November 19-20 at Los Angeles. Headquarters will be the Biltmore Hotel. The papers will cover corrosion of pipe lines, irrigation systems, and airplanes; inhibitors for oil refineries, high temperature ceramic coatings and other topics.

The conference will follow the three-day short course on corrosion at the University of California at Los Angeles, making possible a week of corrosion study.

Several NACE technical committees are expected to meet also.

Following are some biographies of speakers and abstracts of the papers to be given:

Selling Management on Corrosion Control by H. H. Anderson.

H. H. ANDERSON—Retired vice-president of Shell Pipe Line Corp., he has busied himself recently hiring and training the Canadians who will operate the new 24-inch oil pipe line crossing the Canadian Rockies from Edmonton to Vancouver. Mr. Anderson is vice-president and general manager of Trans-Mountain Pipe Line Company, Vancouver, B. C. He is a member of the API General Committee on Transportation and chairman of its committee on Pipe Line Technology. Formerly a vice-president of the National Association of Corrosion Engineers, he was personally responsible for securing over 200 corporate memberships for NACE. Mr. Anderson is considered an expert on management problems involving corrosion control.

Abstract

The huge annual corrosion loss is a serious handicap to the national economy and a direct charge on consumers. Examples are given illustrating typical corrosion losses now taken for granted but which can be avoided. Several arguments for corrosion control are given, including conservation of resources. Management's moral responsibility and duty to recognize and encourage active participation in corrosion control activities is underlined.

Corrosion Prevention and the Gas Industry's New Safety Code by F. A. Hough.

F. A. HOUGH—Now vice-president of Southern Counties Gas Co., of Cal. and chairman of Subcommittee 8, ASA B31 on Gas Transmission and Distribution Facilities, Mr. Hough began his gas industry career in 1925 with Southern Counties. He has been active in design, construction and operation of transmission facilities, has been a member of technical committees of the Pacific Coast Gas Association, is chairman of its technical section and a member of its board of directors. He has been active in AGA work and has devoted much of his time recently to the work of Subcommittee 8.

Abstract

The inadequacy of ASA B31.1 in covering the requirements of the gas distribution and transmission industry are enumerated. Work in progress by Subcommittee 8, whose purpose is to amplify the code to meet important safety problems is explained. One of the safety problems and an economic problem are the consequences of corrosion. Importance of corrosion control and its relation to certain sections of the code are discussed, especially those pertaining to pipe coatings.

Factors Affecting the Corrosion of Aluminum Pipe Used in Sprinkler Irrigation by Mark F. Adams.

MARK F. ADAMS—Associate Chemist, Washington State Institute of Technology, Div. Industrial Research, State College of Washington, he received a PhD in physical chemistry from State College of Washington in 1951. From 1942 to 1947 he spent a major part of his time studying extraction of alumina from clay and was issued a patent for an extraction process involving the use of sulfuric acid.

(Continued on Page 8)

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Authors and Abstracts—

(Continued from Page 6)

sulfurous acids. This introduced corrosion problems. Until 1950 he worked on industrial problems including air pollution resulting from fluorine coming from aluminum reduction plants and after that started full time work on corrosion, principally involving corrosion of aluminum sprinkler pipes. He is a member of NACE and other technical groups.

Abstract

Investigations following the first failure from corrosion of aluminum irrigation pipe in 1950 are reviewed. These essentially eliminate as causes stray currents and soil differences. Among factors established as contributing causes are methods of operation of the system which affect concentration of total solids in the water. These control conductivity of the water and pH. Concentrations of heavy metals found in irrigation water are believed too low to be causative factors.

New Look in Air Transport Maintenance by J. S. Farra.

J. S. FARRA—Service manager for Douglas Aircraft, Inc. He graduated from Stanford in 1936 with a BA in air transportation and joined Douglas in 1936. He worked his way up in the organization to become executive assistant to the general manager in 1941 when he was transferred to Douglas' Chicago Division as executive assistant to the plant manager. He returned to Douglas' Santa Monica offices in 1944 as company service manager, in which he is responsible for the policies and administration of the Douglas Service organization.

Abstract

An industry-wide survey conducted by Douglas Aircraft Company developed data on external corrosion problems of transport aircraft. The follow-up program of Douglas designed to correct some of the causative factors has had far-reaching effect on the approach to corrosion problems by airline management and manufacturing suppliers. The discussion is non-technical, dealing with the economic factors pertinent to commercial air transport planes.

Stress-Corrosion of Airframe Components by R. N. Hooker and J. L. Waisman.

ROBERT N. HOOKER—He is in the metallurgy department of Douglas Aircraft Corp. and has spent considerable time on stress-corrosion and related problems. He holds a BS in metallurgy from Purdue and was employed as a metallurgist at Studebaker Corp. several months after graduation.

JOSEPH L. WAISMAN—Assistant chief metallurgist for Douglas Aircraft Company's Santa Monica Division, he holds a BS in metallurgical engineering from University of Illinois. First employed by McDonnell Aircraft Company at St. Louis, he was then employed by American Car & Foundry Co., Berwick, Pa., as a metallurgical engineer. Since 1943 he has been with Douglas, being chief metallurgist at the firm's Chicago plant during World War II. He is author of numerous papers, including several on corrosion.

Abstract

In efficiently designed structures it is essential to avoid strength loss resulting from corrosion. This makes corrosion prevention a major factor in the design, construction and finishing of airplanes.

Important in this problem is the control of stress-corrosion cracking of high-strength aluminum alloys. Investigation of the effects of sacrificial coatings on stress corrosion cracking are reported.

Some protection was secured but new problems introduced by the materials used makes difficult their large-scale use.

Ceramic Coating Development and Uses by John V. Long.

JOHN V. LONG—He is director of Research for Solar Aircraft Company. Mr. Long has had a varied experience in industry, being employed in various technical capacities with Southern California Bell Telephone Company, Ford Motor Company, University of California, Douglas Aircraft Company, Continental Oil Company. He has been with Solar since 1940 with successive positions as research physicist, assistant director of research and director of research. He holds a degree in physics from UCLA, 1937. He is a member of the Institute of Radio Engineers, American Institute of Physics, Society for Experimental Stress Analysis, American Ceramic Society and British Ceramic Society.

Abstract

Aircraft industry developments since 1943 are reported in which research has developed utility types of ceramic coatings for metal protection. Coatings resulted from the interest of the armed forces in protecting low alloy exhaust manifolds. Effective methods developed extended use of ceramic coatings to exhaust pipes, mufflers, wall heaters, stoves, etc. High alloy coatings were developed later for aircraft reciprocating and jet engine hot parts. Field of use of ceramic coatings is expanding rapidly.

New test methods, application techniques and quality control procedures were developed to assure effective coatings. Laboratory studies indicate they may have many unique properties and may solve many engineering problems.

Use of Organic Inhibitors in Refinery Distillation Process Equipment by G. E. Purdy.

G. E. PURDY—In charge of the Technical Service Corrosion Department of the Tretolite Company, he is responsible for sale and use of the company's corrosion preventives and other special products. He holds a BS in chemical engineering from Missouri School of Mines and Metallurgy.

Abstract

Use of a high molecular weight organic corrosion inhibitor is discussed. Recommended methods are given for use to inhibit losses from such corrosives as hydrogen sulfide, hydrochloric acid, organic acids and salts. Secondary effects are explained, such as detergent effects, which make for less cleanup time and for maintenance of designed heat transfer characteristics. Experiences in 120 refineries in the United States and Canada and 14 refineries in other countries are reviewed.

Corrosion Resistant Materials in Refinery Service—A Review by B. B. Morton.

B. B. MORTON—Mr. Morton, responsible for development and use of nickel products in the petroleum industry for the Development and Research Division of The International Nickel Co., Inc., New York, is well-known to NACE audiences from his many appearances at technical sessions. He has been employed by American Smelting & Refining Co. in Mexico, the Bethlehem Steel Company in Buffalo, and the Standard Oil Development Co. at Baton Rouge, La. He is a member of many technical organizations, including NACE and the author of many papers on metallurgy and corrosion.

Abstract

Requirements for corrosion control in specialized cases which have made it

(Continued on Page 9)

Authors and Abstracts—

(Continued from Page 8)

necessary for petroleum refinery engineers to use special alloys are reviewed. Details of service by alloys are given. Special attention is given to condenser tubes, heating coil tubes, linings for reaction vessels and special alloys to combat reagents such as hydrochloric acid, hydrogen sulfide, hydrofluoric acid, phosphoric acid and other corrosives.

Plastic Tape as a Corrosion Control Coating by Howard D. Segool, manager, Specialized Products, Polyken Products Dept., Kendall Co.

Origin, performance record and future possibilities of plastic tapes as covering are outlined.

Observations on Corrosion in the Oil Industry by R. S. Crog, Research Supervisor, Union Oil Company of California.

Incidence of corrosion in refinery, pipeline, and production divisions of the oil industry are given. General aspects of the corrosive problems involved and remedial measures adopted are explained.

API Papers, Sessions On Corrosion Given

Items listed on the preliminary program for the 33rd Annual meeting of the American Petroleum Institute are extracted here. The meeting will be held at the Conrad Hilton Hotel, Chicago, November 9-12.

Nov. 10—10:45 a.m., Division of Transportation. New Techniques and Current Problems in Controlling Underground Corrosion, O. C. Mudd, Shell Pipe Line Corp., Houston. 2 p.m. Oil Across the Rockies, motion picture to be introduced by H. H. Anderson, Trans Mountain Pipe Line Co., Vancouver, B. C.

Nov. 5 and 6—Division of Refining. 9 a.m. (All Day). Subcommittee on Corrosion, Chairman E. Q. Camp.

Nov. 9—4 p.m. Smoke and Fumes Technical Advisory Committee. Chairman H. G. Vesper.

Nov. 10—9 a.m. Smoke and Fumes Committee. Chairman W. L. Stewart, Jr.

Nov. 8—2 p.m. Subcommittee on External Corrosion. Chairman D. C. Glass.

Subcommittee on Internal Corrosion of Crude-Oil Pipe Lines and Tanks. Chairman R. A. Brannon.

Nov. 9—9 a.m. Subcommittee on External Corrosion. Chairman D. C. Glass.

Subcommittee on Internal Corrosion of Crude-Oil Pipe Lines and Tanks. Chairman R. A. Brannon.

Nov. 10—9 a.m. Committee on Static and Stray Currents. Chairman John C. Howard.

Pennsylvania Biennial.

ASM Meeting Scheduled

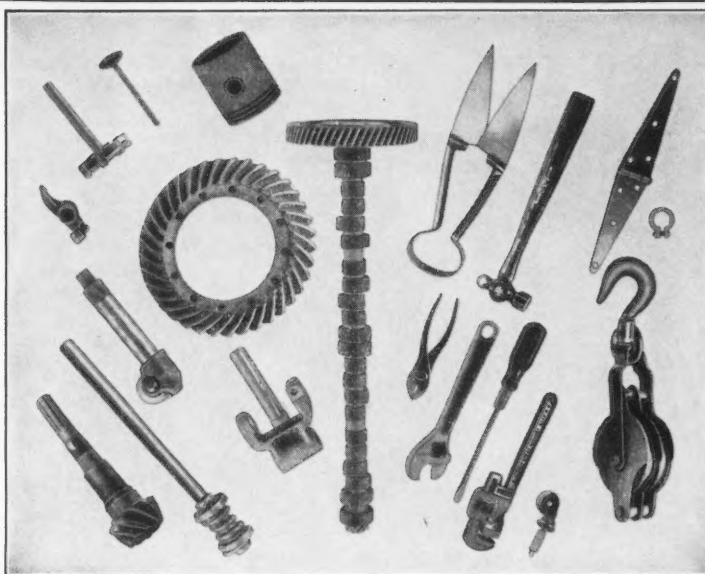
The Ninth Biennial Pennsylvania Interchapter Meeting of the American Society for Metals will be held at State College, Pa., June 13-19, under auspices of Penn State Chapter. Reservations may be obtained from Prof. H. M. Davis, Div. of Metallurgy, Pennsylvania State College, State College, Pa.

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Government Specifications	U.S.A. 57-0-2C, Type II, Class B MIL-C-16232, Type II U.S.A. 51-70-1, Finish 22.02, Class B AN-F-20 Navy Aeronautical M-364 JAN-L-548
Scale of production	Large or small volume; large or small work
Method of application	Dip Barrel tumbling, racked or basketed work
Equipment notes	Immersion tanks of suitable capacity. Cleaning and rinsing stages can be of mild steel. Coating stage can be of heavy mild steel or stainless steel.
Chemicals required	"Permadine" No. 1
Pre-cleaning methods	Any common degreasing method can be used. Alkali cleaning ("Ridosol"), Acid cleaning ("Deoxidine"), Emulsion-alkali cleaning ("Ridosol" - "Ridoline"); vapor degreasing, solvent wiping, etc., are examples. Acid cleaning may need to follow other cleaning methods if rust or scale is present.
Bath Temperature	190° - 205°F.
Coating time	20 - 40 minutes
Coating weight range	1000 - 4000 mgs. per sq. ft.
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Tank structural member held by an engineer on the 1953 Permian Basin Corrosion Tour shows evidence of corrosion. At his feet behind him, is part of the deck of the same tank. The deck showed virtually no corrosion. Injection daily of 12 pounds of ammonia has been made in the vapor space of the tank since August 1950. Name of the engineer was not learned.

In March, 1953 there were more NACE members in Texas alone than there were in the whole United States at the end of 1945, second year of the association's existence.

Permian Basin Tour Attracts 205 From Coast to Coast September 30-October 2

From as far north as Canada and from the East and West Coasts corrosion engineers gathered in Odessa, Texas, September 30 through October 2 to see for themselves what other engineers are doing to whip the corrosion problems presented in the Permian Basin.

There were 205 persons registered for the tours. They boarded buses each morning and spent the day inspecting equipment which had been laid open to their probing fingers and eyes by 37 operating companies in the area. Each evening, participants of all three daily tours gathered in one group for discussions. This allowed each engineer to benefit from the two tours he could not attend.

At each scheduled stop the corrosion history and performance of equipment on display was given in printed form to each member on the tour. In one case performance of cement lined pipe installed in 1942 was given. In another a portion of pipe line was on exhibit, three different sections of which had been covered, each with a different coating. At other locations well casing, sucker rods and tanks were available for inspection.

On the social side, all participants were treated to an informal barbecue at noon Friday, October 2. Members of the Corrosion Tour Steering Committee responsible for the smooth operation of the tour were: John A. Knox, The Western Co., Midland; Thomas M. Newell, Cardinal Chemical, Inc., Odessa; Lamar F. Sudduth, Stanolind Oil & Gas Co., Midland and E. O. Kemper, Permian Enterprises, Inc., Odessa.

Among those present for the tour who have long been active in NACE were: Russell Brannon, Humble Pipe Line Co.; H. E. Waldrip, Gulf Oil Corp. and G. R. Olson, United Gas Pipe Line Co.

75 Corrosion Exhibits Are Viewed on Tour

Performance under corrosive conditions of various types of equipment made from a variety of materials and protected in many different ways were studied first hand by corrosion engineers making the third biennial Permian Basin Corrosion Tour. In all, 75 different exhibits were included on the tours which were held Sept. 30 to Oct. 2.


One tour stop was at the Sun Oil Company's Settles Well No. 6, Howard Glasscock Field. This well was inspected on the 1951 NACE Permian Basin Corrosion Tour. Sucker rods in the well were of Monel, $\frac{5}{8}$ -inch in diameter and were installed in the well after previous service in another well which had received inhibiting treatment. Settles Well No. 6 in which the rods are now installed is one of the most corrosive owned by the company. However, there was no noticeable corrosion of the rods, even though no inhibitor is used. Type of pump used was $1\frac{3}{4}$ -inch x 7-foot nickel iron. It was installed March 18, 1951. The traveling valve has been recapped 11 times. Type of tubing was Hydriil thread 9 percent nickel, installed November 16, 1949. Failures are: four leaks up to inspection in 1951, in each case due to splits at the tong marks. Apparently splits were caused by internal stresses set up by the tongs in making up the joint. There have been two tubing failures since the 1951 inspection, January 22, 1952, tubing parted and February 23, 1952, 64th joint split.

When concrete loosened from cement lined pipe clogged check valves in a gathering system, Transite pipe was substituted in part of the system. Engineers were told the cement lined pipe had been made of coarse sand and cement, installed in 1942. The replacement pipe has given very satisfactory service. The gathering system was on the Magnolia Petroleum Company's Dora Roberts Lease.


On the Humble Oil & Refining Company's J. E. Parker Lease, engineers inspected the interior of a 1000-barrel bolted steel tank coated with one primer and three coats of liquid vinyl plastic in September, 1946. Deck was galvanized prior to coating. Inspected, August, 1948 (except bottom which was covered with 2-inches of sand). Inspected, September, 1949 by NACE Permian Basin Tour and sides were found in excellent condition. Deck had several pinpoint blisters evidently caused by hydrogen sulfide. Sand layer prevented inspection of bottom. Inspected on the NACE 1951 tour, the coating was found to have withstood corrosive action exceptionally well. When inspected by the NACE 1953 Tour, a few blisters were noted.

Carlson "B" pipe used as gathering line in Humble Pipe Line Company's Fuhrman Mascho Field was another point of interest to those on the tour. The line was originally laid in November, 1935 with 485 feet of 4-inch steel pipe. This was replaced in 1945 due to internal corrosion. In 1950, the steel pipe was replaced with plastic pipe. Whereas

(Continued on Page 12)



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CASE HISTORY: A concrete floor subjected to 30% muriatic acid had deteriorated to the point where the acid went through to the floor below. Phenoline 300, mixed with silica filler, was troweled $1/16''$ to $1/4''$ thick over the corroded, caustic-neutralized surface. Leakage was stopped, and the coating looks as good now—after more than a year's service—as it did when applied.

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75 Corrosion Exhibits—

(Continued from Page 10)

previously corrosion and paraffin deposition had been a problem, plastic pipe so far has eliminated both of these troubles. The NACE tour of 1951, as well as later company inspection showed no paraffin deposition. The line operates under about 75 pounds per square inch.

Injection of 12 pounds of ammonia each day since August 1950 has been used as an inhibitor on Humble Pipe Line Company's Ector Station Tank 1589. Injections have been made continuously since the present deck was installed. The previous deck lasted 11 years. The deck of this tank showed virtually complete protection. However, the rafters and other structurals show signs of attack. Two tanks at Powell Station receiving the same type of treatment which were discussed during the NACE 1951 Tour, showed virtually no corrosion when inspected in July 1953, either to decks or structurals.

Requests for additional copies of Corrosion should be addressed to Central Office, NACE, 1061 M & M Bldg., Houston 2, Texas. Single copies are sold to members at 50c each and to non-members at \$1 each. A list of exhausted issues is published frequently during the year in Corrosion.

The 1956 NACE Conference and Exhibition has been scheduled for New York City in March.

REPRINT

Publication 53-I

**Surface Preparation
Of Steels
For Organic and
Other Protective Coatings**

- Second Interim Report of NACE Technical Practices Sub-Committee 6-G on Surface Preparation for Organic Coatings.

This report itemizes the various procedures used to prepare steels for the application of protective coatings. Recommendations as to procedures, standards, safety measures are given. This second report by NACE TP-6G is the culmination of many months of work by committee members. The report has been carefully prepared and checked by committee members with long experience in the coatings application field.

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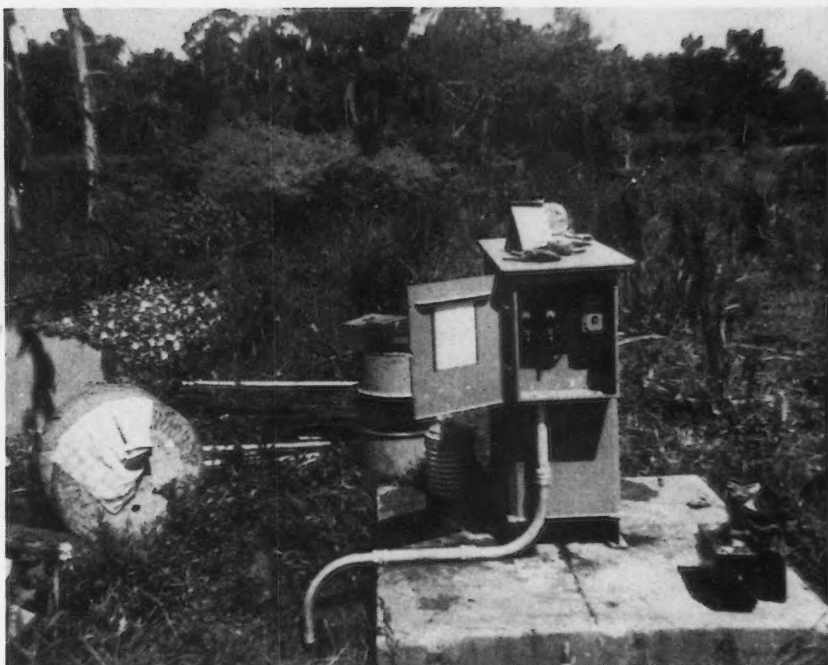
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Practical Control Measures Are Featured at Tulsa

Engineers attending symposia and technical practices committee meetings at the South Central Region Meeting learned how to combat corrosion from the experiences related by top career men in the field.

Technical practices committee meetings were particularly well attended as engineers heard reports on problems they meet in their daily work and exchanged information with other engineers whose problems were similar to theirs.

At the symposia and round table meetings, corrosion men heard papers and discussions on topics ranging from "The Effects of Impurities on the Per-

formance of Magnesium Anodes," to the practical in-the-field suggestion made by one young engineer to use plain household aluminum foil wrap as a temporary ground bed in conducting cathodic protection requirement tests.

Committee Meetings Filled

Standing room only was in effect at some of the technical practices committee meetings where engineers "swapped out" information that would help them on their jobs. Symposia also were well attended, especially when a paper of particular interest to the engineers present was given. Despite the fact the Oil and Gas Transportation Symposium—

General Round Table was held in the afternoon of the last day of the meeting, it was well attended.

Speaking at the business luncheon, Harry Waldrip, chairman of the South Central Region stated he was particularly pleased with the number of technical practices committee meetings held and with the large attendance at them. Mr. Waldrip said technical practices committees were the working groups which developed valuable information on combating corrosion and that the committee reports were evidence to management of what NACE was doing to lessen the financial burden imposed by corrosion on industry.

Approximately 530 engineers registered for the meeting. At the Thursday evening buffet supper, 478 persons enjoyed a 2-hour variety show.

Dunn Addresses Luncheon

Speaker at the business luncheon, Dr. Charles A. Dunn, executive director of engineering research, the Oklahoma Institute of Technology, A & M College, told corrosion engineers they must be more than just technical men. Engineers should participate in civic activities through their church and by active work in Rotary, Lions and other clubs and in the chambers of commerce of their communities.

Oklahoma A & M has instituted a research program which is closely coordinated with industry in Oklahoma, Dr. Dunn said. Chief advantages of the program is that the companies have a large voice in controlling what lines the research is to follow, the technical knowledge of professors and the use of complicated research equipment and laboratories are made available. The school profits because money is made available for research to help provide teachers' salaries, to increase the knowledge of students, and to provide more jobs by expanding industry, he said.

Dallas Meeting Arranged

At the business luncheon, it was decided to hold the 1954 South Central Regional Meeting in Dallas, the 1955 meeting in Houston and the 1956 meeting in Beaumont. This year's regional meeting equalled the national meeting of 1946 in attendance, according to Harry Waldrip, who said there were not many cities large enough to handle the South Central Regional Meeting now.

Tulsa Ladies' Program

The ladies program included on October 7 a brunch at the Mayo Hotel, 10:30 a.m.; option of a tour of Tulsa or a card game at 1:30 p.m. Ladies all were invited to attend the Fellowship hour at 6:30 p.m.

On October 8, luncheon at 12:30 p.m., followed by a fashion show at 1:30 p.m., Oaks Country Club; a buffet dinner at 6:30 p.m., followed by a variety show at 7:30 p.m. at the Mayo Hotel.

Conference on Corrosion

A conference on "Corrosion Control and Prevention" will be one of 59 scheduled to be held during the 3-day Plant Maintenance and Engineering Conference to be held January 25-27 at Hotel Conrad Hilton, Chicago.



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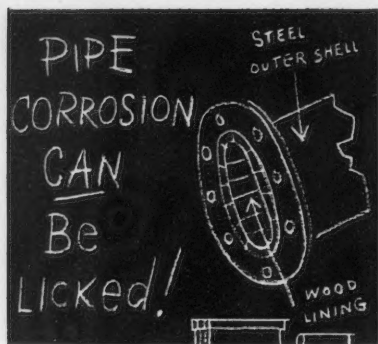


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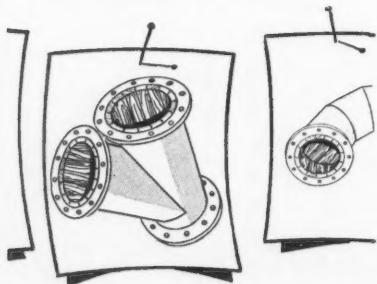


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TECHNICAL PRACTICES SUBCOMMITTEE 18A is shown meeting here at the Mayo Hotel, Tulsa, during the South Central Regional meeting. Standing at left is Lyle R. Sheppard, Shell Pipe Line Corp., Houston, who is outlining structural data and practices for limiting sulfide corrosion losses. This meeting was held October 7 with every seat filled.

Tulsa TP Committee Meeting Highlights

Some highlights of the technical committee meetings are as follows:

TP-18A on Internal Sour Crude Corrosion of Pipe Lines and Tanks. Structural data and practices to limit sulfide corrosion losses discussed.

TP-3 Anodes for Impressed Currents. Various problems in connection with anodes and anode installations were discussed.

TP-14A on Electrical Holiday Inspection of Coatings. Significant discussion involved: 1. Question of optimum voltage for proper testing of coal tar coatings. It was considered that the same criteria could not be applied to mastic or tape coatings because of the distances involved. 2. Grounding should be to the pipe itself. 3. Air gap for testing voltage to be twice the thickness of the testing roller coil. 4. The purpose of the coating inspection is to determine its electrical continuity and not to determine the minimum thickness of the coating. 5. If two tests are made, one should follow the wrapping operation as soon as possible after the coating has cooled sufficiently to prevent deformation by the testing device. A second testing should be made just before line is dropped in the hole.

6. Some present favored only one testing just before dropping the pipe in the hole, which should be done immediately after wrapping is completed. This eliminates skid damage and repairs. 7. Another suggestion called for a spark gap twice the thickness of the coatings. 8. It was conceded the criteria discussed would not necessarily apply to factory coated pipe. 9. The high dielectric strength of plastic tape coatings made criteria designed for testing coal tar coatings inapplicable, it was believed. A spark test of a taped surface would merely test the continuity of the coating, a factor which could be just as readily checked by visual means.

TP-8A on Corrosion by Gulf Coast Cooling Waters. Discussion at this committee meeting centered about what would be a proper testing procedure which could be used in making evaluations of water inhibitors. It was generally believed that accelerated tests were feasible only to detect the obviously ineffective materials and that either a pilot plant or plant test would be necessary to select the best inhibitor from among a group of approximately the

same laboratory characteristics. The tremendous differences among the various cooling systems used indicated that only general recommendations concerning inhibitors could be developed and that ultimate benefits could be determined only after actual use in plant.

TP-1J on Oilfield Structural Plastics. Principal development during this session was the news that Battelle Memorial Institute has been employed by the major producers of structural plastics and a large number of fabricators to develop data on the mechanical properties of the plastics. Experiences related by the committeemen present indicated: 1. Short term tests are not of great value. 2. It is important to know the kind of service in which the material is to be used before starting tests. For example, the well known notch sensitivity of some materials precludes their use under certain conditions even though other conditions were favorable. 3. Stress figures given by sellers frequently were maximum allowable rather than working maximums. 4. Some peculiar behavior of plastics when heated was reported. 5. Thermosetting plastics, although molecularly cross-linked, may have a liquid phase when the temperature is high enough. 6. Ring tests give maximum temperature data. 7. Creep tests of moderate duration necessary to assure correct data. 8. Polyvinyl chlorides with better notch sensitivity are being developed.

TP-1K on Evaluation of Inhibitors for Use in Oil and Gas Wells. A standardized method of laboratory screening is needed.

TP-1 on Corrosion of Oil and Gas Well Equipment. Several subcommittees of TP-1 gave a report of progress to the parent committee. TP-1F reported that only 10 comparisons of sucker rods have been made in the United States.

The chairman reported that E. C. Greco, United Gas Corp. will be the next chairman of TP-1 and that a vice-chairman will be elected by letter ballot. A report on the Permian Basin Corrosion Tour was given and there was a report on the A&M Short Course on Corrosion.

TP-6B on Protective Coatings for Resistance to Atmospheric Corrosion. The committee discussed experiences with

(Continued on Page 19)

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BOOK REVIEWS

American Standard Specifications for Cast Iron Pit Cast Pipe for Water or Other Liquids. 6 x 9, paper cover, 22 pages. Jan., 1953. American Water Works Association, 521 Fifth Ave., New York 17, N. Y. Per copy, 45c. Complete specifications for quality, inspection procedure, cutting, cleaning, testing, weighing, tables of standard dimensions, thicknesses and weights, are included.

American Standard Specifications for Cast Iron Pit Cast Pipe for Gas. 6 x 9, paper cover, 18 pages. 1953. American Standards Association, 70 East 45th St., New York 17, N. Y. Price not given.

Description, casting practices, quality, records, marking, inspection, tolerances, cleaning, testing, weighing, exterior coatings and tables of standard thicknesses, measurements and weights are included.

American Standard Specifications for Cement Mortar Linings for Cast Iron Pipe and Fittings. 6 x 9, paper cover, 5 pages. March, 1953. American Water Works Association, 521 Fifth Ave., New York 17, N. Y. Per copy, 35c.

Characteristics of cement, sand, accepted specifications, water, preparation, application, thickness, curing of cement linings. Exterior coatings and testing of bituminous coatings given.

American Standard Specifications for Cast Iron Pipe Centrifugally Cast in Metal Molds for Water and Other Liquids. 6 x 9, paper cover, 17 pages. March, 1953. American Water Works Association, 521 Fifth Ave., New York 17, N. Y. Per copy, 40c.

Definitions, description, casting methods, quality, variation tolerances, cleaning and inspecting, testing, linings and exterior coatings, rejection procedure, standard thicknesses, diameters and weights are included.

American Standard Specifications for Cast Iron Pipe Centrifugally Cast in Metal Molds for Gas. 6 x 9 inches, paper cover, 20 pages. 1953. American Standards Association, 70 East 45th St., New York 17, N. Y. Price not given.

Definitions, description, quality control, records, marking, inspection, variation tolerances, cleaning and inspecting, testing, exterior coatings, rejection criteria, and tables of standard dimensions of bells and sockets, thicknesses, diameters and weights are included.

Review of ASTM Research. 8½ x 11¼ inches, paper, 24 pages. May, 1953. American Society for Testing Materials, 1916 Race St., Philadelphia. Free.

Major ASTM research activities are reviewed as to past and present history and work in progress.

American Standard Specifications for Cast Iron Pipe Centrifugally Cast in Sand-Lined Molds for Water or Other Liquids. 6 x 9, paper cover, 22 pages. March 1953. American Water Works Association, 521 Fifth Ave., New York 17, N. Y. Per copy, 45c.

Definitions, descriptions, casting and quality, records, inspection, tolerances of variations, cleaning and inspecting, linings and exterior coatings, tests, rejection criteria and tables of standard dimensions of bells, sockets, etc., standard thicknesses, diameters and weights are included.

Tulsa TP Committee—

(Continued from Page 16)

various coatings of steel bridges, tanks, towers, fences, railroad cars and other general uses of coatings exposed to atmospheric corrosion. A coating evaluation chart that is being prepared by the subcommittee was discussed at length.

TP-1D Sour Oil Well Corrosion. The committee discussed corrosion in the vapor space of the tubing-casing annulus, corrosion of rods, pumps and inside of tubing and new developments in the use of plastic pipe, plastic coatings and inhibitors.

TP-1H Corrosion of Oil String Casing. Recent developments in the corrosion of production and surface string casing in oil and gas wells were discussed. Special emphasis was placed on the measures being employed to combat the extensive corrosion of oil string casing equipment in the East Texas Field and the West Texas-New Mexico area.

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Corrosion Engineer. Considerable field, design, research and development experience for protection of communication cables, pipe lines, power substations, cables and transmission towers. West Coast preferred but travel considered. CORROSION, Box 53-15.

Corrosion Engineer (BSGE), 4 years experience with major design consultant; installation, maintenance cathodic protection systems for distribution and transmission piping, desires position with less travel demands. CORROSION, Box 53-16.

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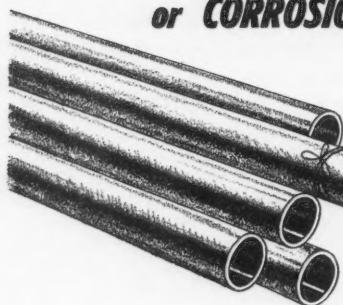


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Who's Who

Leonard W. Hartkemeier—Co-chairman of the Educational Committee for the 10th Annual NACE Conference to be given at Kansas City. Mr. Hartkemeier is associate professor of chemistry at Colorado School of Mines, Golden. He holds degrees in chemistry and chemical engineering from University of Louisville, University of Minnesota and has done work at University of Colorado. Since 1921 he has held various positions involving chemistry at universities, Minnesota State Highway Dept., and Northern Pacific Railroad. He has been associate professor at Golden since 1935. He is a consulting chemical engineer. Among other organizations he is a member of NACE, ACS and several fraternities. He is married and lives in Denver.

O. W. Wade—Senior Corrosion Engineer with Transcontinental Gas Corp., Houston, he is chairman of the Cathodic Protection Symposium. Mr. Wade's first pipe line work was with Socony-Vacuum Oil Company's White Eagle Division in 1936. He became interested in corrosion problems while employed as test engineer for Pratt & Whitney Aircraft Company in 1943. He returned to pipe line work with Great Lakes Pipe Line Company in 1945 as Division Corrosion Engineer, and became affiliated with Transcontinental in 1950.

Jack P. Barrett—Technical Group Leader of the corrosion section, Production Research Laboratory, Stanolind Oil and Gas Company, Tulsa, Mr. Barrett is co-chairman of the Pipe Line and Underground Corrosion Round Table to be held at Kansas City. He is chairman of NACE Technical Practices Subcommittee 1 H on Corrosion of Oil String Casing and is active on other committees concerned with oil production equipment corrosion. He has been doing corrosion research since he joined Stanolind in 1945. He holds a BS from William Jewell College, Liberty, Mo.

Frank I. Dorr, Jr.—Chief Corrosion Engineer for the Trunkline Gas Company, Houston. Mr. Dorr has attended the Universities of Alabama and Houston and before starting work for Trunkline in 1951, was employed successively by the Fluor Corporation and United Gas Corporation. Mr. Dorr is chairman of the Pipe Line Group Discussions to be held during the Kansas City Conference next March.

Stainless Steel Paper Has Been Committed

"Effect of Design, Fabrication and Installation on the Performance of Stainless Steel Equipment," is the title of a paper by James A. Collins, who is in the Engineering Department of E. I. du Pont de Nemours & Co., Inc., Wilmington, Del., to be given at the NACE Tenth Annual Conference at Kansas City. The paper is one of those to be presented during the Chemical Industry Symposium on March 17. Presentation of eight papers in two sessions of this symposium is contemplated.

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Two Films on Stress Corrosion to be Given At Kansas City Meeting

Two films on stress corrosion and a paper co-authored by J. J. Harwood, Office of Naval Research, Washington, have been scheduled for presentation as a part of the Corrosion Principles Symposium at Kansas City next March. Hugh P. Godard, of Aluminium Laboratories, Ltd., chairman of the symposium announced these items on the program. The NACE Tenth Annual Conference and Exhibition will be held March 15-19, 1954. Mr. Harwood was the author of an exhaustive review of the stress corrosion phenomenon published in CORROSION few years past.

One of the films will deal with stress corrosion cracking of a magnesium base alloy, developed under the supervision of R. D. Williams, Aluminum Research Laboratories, New Kensington, Pa. The other was developed under the supervision of M. G. Fontana of Ohio State University.

Fisher Accepts Post On Discussion Session

A. O. Fisher, Monsanto Chemical Company, Merrimac Division, Everett Station, Boston, Mass., has accepted the post of co-chairman of the General Corrosion Problems Round Table to be given during the NACE Tenth Annual Conference and Exhibition. A concurrent obligation to head a similar program at the 1955 NACE Conference is assumed with this position by Mr. Fisher.

BOOK REVIEWS

American Standard Specifications for Cast Iron Pipe Centrifugally Cast in Sand-Lined Molds for Gas. 6 x 9, paper cover, 23 pages. 1953. American Standards Association, 70 East 45th St., New York 17, N. Y. Price not given.

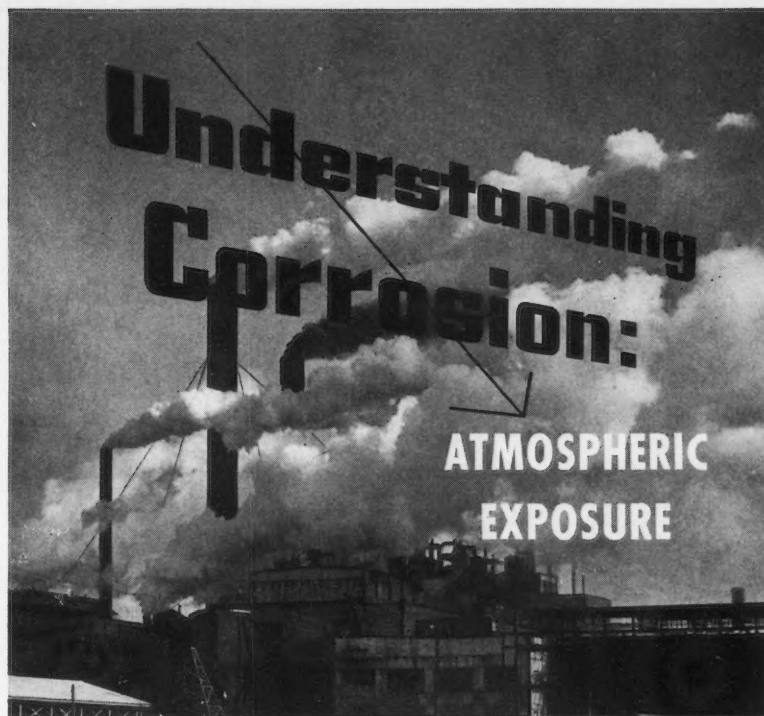
Definitions, description, quality, records, marking, inspection, tolerances of variations, cleaning, weighing, exterior coatings, tests and rejection criteria are covered. Tables include standard dimensions for bells, etc., thicknesses, diameters and weights.

American Standard Specifications for Short-Body Cast-Iron Fittings, 3 Inch to 12 Inch, for 250-PSI Water Pressure Plus Water Hammer. 6 x 9, 8 pages, paper cover. April, 1953. American Water Works Association, 521 Fifth Ave., New York 17, N. Y. Per copy\$0.35

Description, casting, quality, records, marking, inspection, tolerance variations, cleaning and inspecting, weighing, testing and tables of dimensions are included.

Constructors' Meeting

The National Constructors Association will hold its annual meeting at Hotel Commodore, New York City on January 12-14.



The extent to which metal will corrode in atmosphere—or even whether it will corrode at all to any appreciable degree—is determined primarily by the moisture content of air. While deterioration at normal temperatures and humidities of less than 35% is so slow as to be almost negligible, the rate accelerates rapidly beyond a critical point of approximately 65%. This activity is intensified when such contaminants as hydrogen sulfide or sulfur dioxide are absorbed from industrial atmospheres. Impingement of solids, which tends to hold this acid film in contact with metal, localizes and further advances corrosive attack.

When exposure to atmosphere includes also exposure to sunlight and to the variables of weather, the situation becomes more complex. Such factors as the composition of metal and of the protective rust film that forms upon it, the length of time surfaces are wet, the extent

to which they retain moisture, and whether they may be bared intermittently by heavy rainfall are influential in determining metal life.

An understanding of the mechanism of corrosion in all of its varied phases is an obvious requisite to prescribing methods of control. Thirty-five years' study and evaluation of industrial corrosion problems and the formulation of protective coatings to meet them has taught us something about corrosion and the ways in which it may be checked successfully.

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An introduction to **Flowrator Meters**, (Catalog 10-A-10) comparing these meters with variable area types and variable head meters, is available from Fischer & Porter Company, Hathboro, Pa.

Plax Corp., West Hartford, Conn., manufacturer of plastics, has been purchased by Owens-Illinois Glass Co., Toledo, Ohio.

Ilminite, a raw material from which titanium is derived, will be produced at a new \$3,000,000 plant to be constructed near Lawtey, Fla., for E. I. duPont de Nemours & Co.

Architectural Porcelain Enamel will be produced at a new plant of Avondale Marine Ways, Inc., at Avondale, La.

Boltaron reducing bushings, plugs, unions and caps have been added to the line of fittings manufactured by H. N. Hartwell & Son, Inc., Boston, making possible complete piping systems of this polyvinyl chloride material.

Varian Model V-4300 high resolution nuclear magnetic resonance spectrometers are described in Publication No. 40 available from Varian Associates, 524 Hansen Way, Palo Alto, Cal.

Tantalum strip, custom rolled up to 6 inches wide and down to 0.0005-inch, to tolerances as close as plus or minus .0001-inch is available from Industrial Division, American Silver Company, 3607 Prince St., Flushing 54, N. Y.

Scientific Translations Center, Science Division, Library of Congress, Washington 25, D. C., has a center for photo-duplicating foreign scientific translations, established by the National Science Foundation. Monthly lists of translations will be issued, Industrial Research Newsletter of Armour Research Foundation reports.

Statement Required by the Act of August 24, 1912, As Amended by the Acts of March 3, 1933, and July 2, 1946 (Title 39, United States Code, Section 233) Showing the Ownership, Management, and Circulation of CORROSION, published Monthly at Houston, Texas, for 31 September, 1953.

1. The names and addresses of the publisher, editor, managing editor, and business managers are: Publisher, National Association of Corrosion Engineers, 1061 M & M Bldg., Houston, Texas; Editor, Ivy M. Parker, P. O. Box 1743, Atlanta, Georgia; Managing Editor, Norman E. Hamner, 1061 M & M Bldg., Houston, Texas; Business Manager, A. B. Campbell, 1061 M & M Bldg., Houston, Texas.

2. The owner is: National Association of Corrosion Engineers, 1061 M & M Bldg., Houston 2, Texas.

3. The known bondholders, mortgagees, and other security holders owning or holding 1 percent or more of total amount of bonds, mortgages, or other securities are: None.

A. B. CAMPBELL,
Business Manager

Sworn to and subscribed before me this 29th day of September, 1953, Ann Graham, (my commission expires June 1, 1954).

Bitumastic Pipe Line—Handbook—Gas and Oil, a hard back, cloth-covered illustrated book is available on request on firm letterheads from Mavor-Kelly Company, M & M Building, Houston 2, Texas. The 8½ x 11 inch book is printed in two colors and has 118 pages. Designed for the assistance of pipe line engineers and contractors and others interested in pipe line construction, it covers properties of Bitumastic coatings, machines for cleaning, priming, coatings and wrapping pipe both over the ditch and plant; tells of the different types of coating plants, shows the technique for laying coated pipe, how to recondition pipe and gives comprehensive technical data on Bitumastic pipe coatings, as well as step-by-step procedure for application, cleaning, coating holiday detection, explains the fundamentals of cathodic protection of underground pipe and recommends good practice on pipe coating jobs. The book was published by Koppous Company.

Electroplating is possible now on a fully automatic machine developed by Wagner Bros., Inc., performs all of the necessary manipulations required in any plating cycle.

Porcelain-Face panels will comprise 18,000 square feet of the outside curtain walls of the Hartford, Conn., Hotel Statler. A saving of nearly a foot of space per room will be gained by substituting the 1½-inch thick panels for the customary 12-inch masonry walls. Seaportel Metals, Inc., 28-20 Borden Ave., Long Island City 1, N. Y. will make the panels.

Glydag B, a colloidal graphite dispersed in 1,30 butylene glycol has been developed by Acheson Colloids Co., Port Huron, Mich., as a rubber lubricant. The materials also may be used to re-lubricate molded rubber bearings whose porities porosities have been exhausted of original graphite content.

Toncray Equipment Co., 1732 Blake St., Denver, Col., has been named a representative of Linatex Corp. of America.

Speedline corrosion-resistant fittings for use with light wall pipe are described in a 24-page catalog by Horace T. Potts Co., Philadelphia. The fittings are characterized by extended straight sections from each elbow, permitting easy attachment of slip-on or insert flanges. The fittings are designed for use with Schedule 5 light wall pipe. Tables give dimensions and mechanical strength information.

Data on Tubing and pipe for high temperature and pressure use is contained in a six-page folder TDC 163 available from Tubular Products Division, Babcock & Wilcox Co., Beaver Falls, Pa.

Gilsulate, a blend of Gilsonite, a solidified petroleum found in Utah's Uintah Basin, is poured around pipe after it is laid in the trench. When hot substances are run through the pipe material next to the pipe is fused to it, and in a zone out from this some of the material is sintered; the remainder, unaffected by the heat, forms an inert barrier around

(Continued on Page 23)

NEW PRODUCTS Materials — Service — Literature

(Continued from Page 22)

the pipe. Reductions of heat losses vs bare pipe up to 92% are claimed. Manufacturer, American Gilsonite Co., Salt Lake City, Utah, claims the material forms a waterproof, inert coating around the pipe, effectively limiting corrosion.

Careyduct, an all-asbestos prefabricated sectional duct, manufactured by Philip Carey Mfg. Co., Lockland, Cincinnati, is recommended for use as a substitute for metal insulated duct or uninsulated metal duct. The product is available in standard rectangular and circular cross-sections, in one-half and one-inch thicknesses. In addition to its insulating characteristics the company points to the inherent inertness of asbestos as being valuable in ducting corrosive or moist vapors, gaining at the same time noise reduction. Fabricating is simple, most joints being made by cementing. Types and styles of ducts, fabricating steps, tables of equivalents to metal duct sizes, insulation characteristics, friction losses and other data are included in a catalog "Careyduct—Service to Air Conditioning Industry" File No. 30-D-4 available from Adams Equipment Co., 3412 LaBranch, Houston 4, Texas.

Iron Ore containing at least 65 percent iron and less than 2 percent silica will be extracted as a by-product from nickel ores in the Sudbury District of Ontario. International Nickel Company of Canada, Ltd. has begun construction of a \$16,000,000 plant in the Copper Cliff area designed ultimately to produce 1,000,000 tons of high-grade ore yearly, in addition to nickel. Extraction will be by a newly developed process. The company visualizes the possibility that other elements, such as sulfur may be recovered from the complex Sudbury ores.

Thiokol synthetic rubbers are described briefly in a 4-page bulletin available from Thiokol Chemical Corp., 780 N. Clinton Ave., Trenton 7, N. J.

What Silicones Do is described in a 1953-54 Reference Guide to Dow Silicone Products, available from Dow Corning Corp., Midland, Mich. Various uses for silicones, as adhesives, release agents, greases, water repellants, protective coating resins and others are described.

PERSONALS

Donald M. Garrison has been made sales promotion representative on new gas pipeline products and corrosion products by Dresser Manufacturing Division of Dresser Industries, Inc., Bradford, Pa. He will have headquarters at Bradford.

George A. Davis has been named New England sales representative of The Carpenter Steel Company's Alloy Tube Division, Union, N. J.

Ernest Nuber is the new sales manager of the instrument division of The Bristol Company, Waterbury, Conn.

L. W. Davis, recently was appointed chief metallurgist of Kaiser Aluminum & Chemical Corp., Hazelthorpe, Md., works.

PERSONALS

John W. Pennington, now manager of the new technical department of the Metal Products Division of Koppers Company, Inc., will supervise all research and development activities for all products departments of the division and liaison with Kopper's central research organization.

A. A. Fomilyant has been named general manager of Rockwell Manufacturing Company's Macnick Division at Tulsa, Okla. He succeeded **W. M. O'Connor**, who will be liaison between sales and production of the Division's Pittsburgh headquarters and divisional plants and offices.

Jack W. Harris has been named sales engineer in charge of valve sales for process industries by Beaumont Iron Works Company, a subsidiary of American Locomotive Company. Beaumont Iron Works manufactures non-lubricated valves suitable for corrosion and high temperature service. Mr. Harris, formerly with Cameron Iron Works and experienced otherwise in oil refinery problems, will be located at the 1404 Dunlavy Street, Houston, offices of the firm. Long an active NACE member, Mr. Harris was exhibits chairman for the NACE Galveston Conference.

Richard F. Protiva has been named district sales engineer for Heil Process Equipment Corp., Cleveland.

Wesley E. Weber has been appointed a development engineer by Furane Plastics Inc., 4516 Brazil St., Los Angeles 39, Cal. He will devote himself to sales of epoxy resins.

Electro Rust-Proofing Corp., Belleville, N. J. has recently announced the appointment of **R. J. Fitzgerald** as district manager of its Middle Atlantic States Div., including southern Pennsylvania, Maryland, Delaware, Virginia and North Carolina.

A. B. Capron, formerly chief engineer, has been named assistant works manager in charge of the tube mills and engineering, and **Newell Hamilton**, formerly superintendent of the steel mill, has been appointed manager of steel operations in the Tubular Products Div., The Babcock & Wilcox Co.

Ken W. Grader has been appointed Chicago District Representative for the Heil Process Equipment Corp. He will make his headquarters at 400 W. Madison Ave. The firm manufactures chemical proof tanks, tank linings, impervious graphite heat exchange equipment, lead anodes, steam jet agitators and Rigidon plastic exhaust hoods and duct work.

Nields B. Haas has been appointed Mid-Eastern regional sales manager for the Alloy Tube Div., Union, N. J. of The Carpenter Steel Co. He will supervise sales activity in a 14-state region from New York to Florida, and as far west as Michigan.



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IN PIPE"

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Straight from the Kettle
on PIPE PROTECTION

★
By Boyd Mayes

• Met up with an old pipeliner friend and customer the other day I hadn't personally seen for some time. Got to talking about the changing times — lines, little and big, people in general, and business ups and downs.

Asked him, by way of information, if he had a reason for "buying my wares" so often over the years — "stead of somebody else's. He says: "Too many people in business selling expendable goods — darn few selling dependable." He went on to say he bought the latter every time he could 'cause he'd sorta got used to QUALITY.

Sounded good to us, and we thanked him for keeping us on his "buying list."

We are sorta proud of our over a quarter of a century of service to just about everybody in the pipe line business . . . and we keep right on believing that doing our special job well is assurance we'll see customers again and again. "Cleaning, Coating, Wrapping and Reconditioning Pipe" is still our business.

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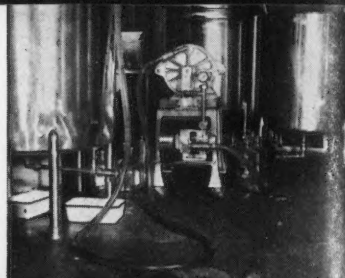
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expensive corrosion problems

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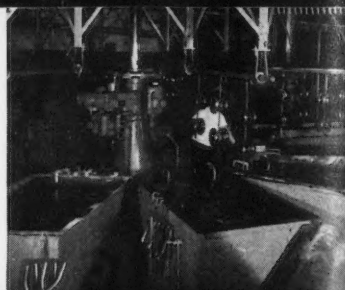
TYGON Tubing is widely used in both plant and laboratory. In the "lab," TYGON'S glass-like clarity, full flexibility, smooth surfaces, non-contaminating and non-oxidizing properties make it quicker, easier, safer and cheaper to use in the most intricate "set-ups" or with the most delicate solutions. In the plant, these same properties plus its light weight, high strength, excellent abrasion resistance and easy installation, give TYGON tremendous advantages over conventional piping. TYGON Tubing is available in six standard formulations, in clear or glossy black, with a wide range of physical, chemical and electrical properties. Sizes range from .12" I.D. to 2" I.D. Braided jacket reinforcement in fabric, plastic and stainless steel is also available for use with constant working pressures up to 300 psi.



As linings

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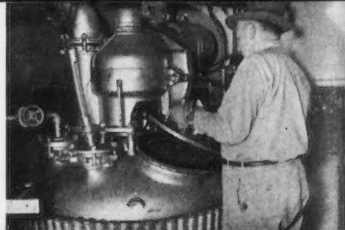
TYGON press-polished sheeting in thicknesses of 3/32" or 3/16" makes it ideally suited to the protection of tanks, tank cars, diffusional towers, vats, reactors, bins, hoppers, troughs, pipe and other processing equipment against a wide range of chemicals. Its unique resistance against oxidizing acids, oils, greases and certain solvents permits the use of TYGON in jobs other linings cannot handle. Its wear resistance assures long life with the most abrasive materials. Its flexibility permits close conformance to the most intricately shaped equipment. Its lack of the need for "curing" makes possible installations of virtually any size. TYGON, for lining work, is available in two standard compounds—TL 104 (Black) for general use and TL 104-A (White) where solution visibility is desired.



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TYGON PROVIDES POSITIVE, ENDURING SEALS FOR ALL TYPES OF PROCESSING EQUIPMENT

Die-cut, molded, or extruded, TYGON is the sure answer to tough gasketing jobs in chemical processing or general industrial equipment. Its chemical resistance, abrasion resistance, resilience, high strength, non-contaminating and non-oxidizing properties make it practical to use under a wide range of operating conditions. TYGON gaskets can be die-cut from calendered or press-polished sheeting (1/64" to 1/2" thick); can be molded in practically any size or shape; can be extruded as tubing, solid cord, strip, or channel in continuous lengths. A number of standard compounds are available.



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487C

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Corrosion Abstracts

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2. TESTING

2.4 Instrumentation

2.4.2, 2.3.9

Rapid Analysis of Hydrogen in Molten Steel by Vacuum Fusion Method. Y. ISHIHARA AND S. SAWA. Paper before 1st World Metallurgical Congr., Detroit, Oct. 1951. Proc. 1st World Metallurgical Congr., *Am. Soc. Metals*, 1951, p. 247-255.

Rapid analytical method for hydrogen in steel is described. The method involves vacuum fusion of the steel sample and subsequent measurement of the thermal conductivity of the extracted gas. Applications of the apparatus in practice are given. Diagrams, graphs and tables are included.—INCO. 4891

2.4.2, 4.6.4, 7.4.2

Dynamically Testing Corrosion in Cooling Water Systems. RALPH D. MILLER. *Corrosion*, 7, No. 9, 1 (News Section) (1951) Sept.

A dynamic tester developed to provide a quick means of determining water containing various concentrations of contaminants. The amount of corrosion or scaling can be easily tested. Applicable to any metal or alloy.—MR. 4945

2.4.2, 4.6.10, 3.4.6

Portable Meter for Determining Dissolved Oxygen. G. A. MARSH. *Pure Oil Co. Anal. Chem.*, 23, No. 10, 1427-1431 (1951) Oct.

Determination of dissolved oxygen to

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AER—Aeronautical Engineering Review, Institute of Aeronautical Sciences, Inc. 2 East 64th St., New York 21, N. Y.

ALL—The Abstract Bulletin, Aluminum Laboratories, Ltd. P. O. Box 84, Kingston, Ontario.

AWWA—Journal, American Water Works Association, Amer. Water Works Assoc., 521 Fifth Ave., New York 17, N. Y.

BL—Current Technical Literature, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

BTR—Battelle Technical Review, Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio.

BNF—Bulletin; British Non-Ferrous Metals Research Association. 81-91 Euston St., London NW 1, England.

CALCO—Calco Chemical Division, American Cyanamid Corp. Bound Brook, New Jersey.

CE—Chemical Engineering, McGraw Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

CEC—Consolidated Edison Co. of New York, Inc. 4 Irving Place, New York 3, New York.

EL—Electroplating. 83/85 Udney Park Road, Teddington, Middlesex, England.

EW—Electrical World, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

GPC—General Petroleum Corp. of California. 2525 East 37th St., Los Angeles 11, Calif.

IIM—Transactions, The Indian Institute of Metals, 23-B, Netaji Subhas Road, P. O. Box 737, Calcutta, India.

INCO—The International Nickel Co., Inc. 67 Wall Street, New York 5, New York.

IP—Institute of Petroleum. 26 Portland Place, London W#1, England.

JSPS—Japan Society for the Promotion of Science, Address: Mr. Hayata Shigeno, Secretary, Committee of Preventing Corrosion, c/o Government Chemical Industrial Research Institute, 1-Chrome Nakameguro, Meguro-ku, Tokyo, Japan.

MA—Metallurgical Abstracts, Institute of Metals, London, England. 4 Grosvenor Gardens, London SW 1, England.

MI—Metallurgia Italiana. Associazione Italiana di Metallurgia. Via S. Paola, 10, Milano, Italia.

MR—Metals Review, American Society of Metals. 7301 Euclid Ave., Cleveland 3, Ohio.

NALCO—National Aluminate Corp. 6216 West 66th Place, Chicago 38, Illinois.

NBS—National Bureau of Standards. Supt. of Documents, U. S. Gov't Printing Office, Washington 25, D. C.

NSA—Nuclear Science Abstracts. United States Atomic Energy Commission, Technical Information Division, Oak Ridge, Tenn.

PDA—Prevention Deterioration Abstracts. National Research Council, 2101 Constitution Ave., Washington 25, D. C.

RA—Refrigeration Abstracts, American Society of Refrigeration Engineers. 40 West 40th St., New York 18, N. Y.

RM—Revue de Metallurgie, Paris, France. 5 Cite Pigalle, Paris (9e), France.

RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London. Waldegrave Rd., Teddington, Middlesex.

SE—Stahl Und Eisen, Verlag Stahlseisen, M. B. H., Dusseldorf, August-Thyssen Str. 1. Postcheck Kohn 4110, (22a) Dusseldorf, Germany.

TIME—Transactions of Institute of Marine Engineers. 85 The Minories, London EC 3, England.

UOP—Universal Oil Products. 310 South Michigan Ave., Chicago, Illinois.

ZDA—Zinc Development Association. Lincoln House, Turl Street, Oxford, England.

check the operation of brine-treating plants is accomplished by a polarographic instrument using a rotating platinum micro-electrode. As a corrosion research tool, this apparatus saves considerable time in estimating corrosiveness of brines, where under some conditions the corrosion rate of immersed steel is roughly proportional to the concentration of dissolved oxygen. Tables, diagrams of the apparatus and graphs are included. 5 references.—INCO. 4840

2.4.2, 7.1, 3.5.9

Advances in High-Temperature Strain Gages and Their Application to the Measurement of Vibratory Stresses in Hollow Turbine Blades during Engine Operation. R. H. KEMP, W. C. MORGAN AND S. S. MANSON. *Proc. Soc. Exp. Stress. Anal.*, 8, No. 2, 209-228 (1951); *Applied Mechanics Rev.*, 4, No. 7, 404 (1951) July.

Improved high-temperature strain gage and techniques of installation enabling

the measurement of vibratory strains in a turbine blade up to 1500° F., and measurement of steady-state strains up to 900° F. satisfactorily. The combination of materials used for the measurement of vibratory strains up to temperatures of 1500° F. consists of 0.001 inch Karma, or 0.001 inch 80 platinum-20 iridium strain-sensitive wire, 0.010 inch 80 platinum-20 iridium tubular lead wires, L-6AC precoat, and Quigley AAA No. 1925 cover ceramic. Only Karma wire in the annealed state is suitable as the strain-sensitive element for a strain gage capable of measuring steady-state strains up to 900° F. A distinct advantage of the strain gage is the feasibility of its prefabrication. The strain-sensitive and lead wires are joined together mechanically through the use of a tubular lead, thus avoiding the difficulties of welding. Results of the measurement of vibratory strains in instrumented blades of gas-

turbine wheel during turbine operation are given.—INCO. 4749

2.4.3

The Role of Non-Destructive Testing in the Economics of Castings. JOHN W. JUPPENLATZ. A. S. T. M. Symposium on the Role of Non-Destructive Testing in the Economics of Production, 1951, p. 102-108; discussion, p. 109-111.

Increasing severity of service requirements calls for more critical and exacting inspection. Destructive and non-destructive tests are briefly discussed. Factors of safety in castings have been reduced in a few years from 8 to 3 or 4, and in some cases to 1 or 2. Many specifications today call for non-destructive testing, without any real appreciation of such testing or its related factors. A general sequence of non-destructive inspection of castings, including visual, penetrant, magnetic particle, radiographic, pressure or proof, and service testing is suggested.—MA. 4731

2.4.3

Non-Destructive Method of Identification by Mechanical Sounding of Materials and Their Assemblies. (In French). P. LE ROLLAND AND P. SORIN. *Metaux: Corrosion-Industries*, 26, 198-204 (1951) May.

Treats theory of double-pendulum method mathematically and discusses identification of structures and materials. Applications to systematic study of laws of resistance of materials.—MR. 4760

2.4.3, 1.3

Experience in the Non-Destructive Testing of Materials. K. MATTHAES. *Metall.*, 5, Nos. 23/24, 544-546 (1951).

Various methods of non-destructive testing are briefly reviewed, viz. hardness testing, simple optical methods for the evaluation of surface finish, radiography, and the detection of cracks by liquid-penetration methods including fluoroscopy, by magnetic powder, and by eddy-current methods. Their relative merits are assessed in comparison with the more customary methods of mechanical testing and chemical analysis.—MA. 4842

2.4.3, 1.3, 1.2.1

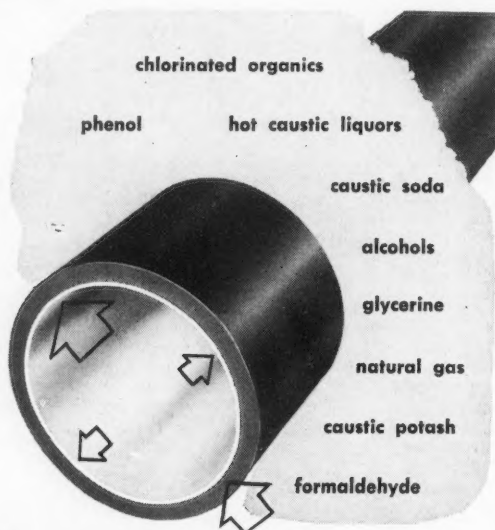
A Basic Guide for Management's Choice of Non-Destructive Tests. ROBERT C. MCMASTER AND SAMUEL A. WENK. *Am. Soc. Testing Materials. Symposium on the Role of Non-Destructive Testing in the Economics of Production*, (1951) 3-82.

250 patents and approximately 500 technical articles relating to the basic principles and essential features of 12 basic non-destructive test methods are summarized. The nature and critical characteristics of the tests are discussed by references to existing commercial instruments, and the operational principle of each test is stated. The test methods discussed comprise: 1. electric current conduction, 2. electromagnetic induction, 3. magnetic field, 4. electric field, 5. thermal, 6. penetrating radiation, 7. mechanical vibration, 8. luminous energy, 9. pressure leak and penetrant, 10. mechanical calliper or gauge, 11. chemical spot, and 12. triboelectric non-destructive tests. The patents are classified by method and listed chronologically, and important operating features are given in 12 tables. 492 references.—MA. 4809

2.4.3, 1.6

Magnetic and Electrical Methods of Non-Destructive Testing. D. M. LEWIS.

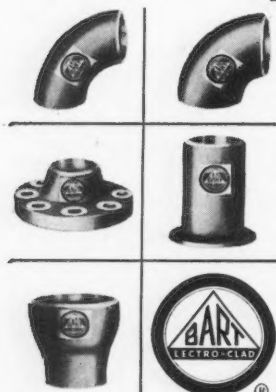
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242 pages. 1951. George Allen & Unwin, Ltd., London. £1 15s.

The above is intended as a work of reference for the technicians in ferrous and nonferrous metal making and working industries. Includes numerous graphs, diagrams, and illustrations.—BTR. 4765

3. CHARACTERISTIC CORROSION PHENOMENA

3.5 Physical and Mechanical Effects

3.5.9, 4.3.3

Oil Ash Corrosion of Materials at Elevated Temperatures. C. T. EVANS, JR. American Society for Testing Materials, "Symposium on Corrosion of Materials by Elevated Temperatures," 1951, p. 59-105; disc., p. 106-113.

Presents details of comprehensive investigation of the above for a wide variety of oil-ash compositions and for 9 representative stainless steels and other high-temperature alloys, at several temperatures between 1000 and 1500° F. Value of several protective coatings of ceramic, diffusion, or metallizing types was also determined. Numerous graphs, tables, micrographs, and photographs. 38 references.—BLR.

3.5.9, 6.2.5, 3.4.6, 3.2.3

Studies of High Temperature Oxidation of Stainless Steels: (Electron Diffraction and Quantitative Observation). (In English). I. IITAKA, T. NAKAYAMA AND K. SEKIGUCHI. *J. Sci. Research Inst. (Japan)*, 45, 57-64 (1951) July.

The resistance to oxidation of iron-nickel-chromium, iron-chromium, and iron-nickel-chromium-molybdenum stainless steels was investigated at 900° C. Electron diffraction showed that a nickel layer coated with fine nickel-mono-oxide crystals was formed under the outer protective oxide film, retarding the diffusion of iron, chromium and nickel atoms to the surface. High-molybdenum stainless steel is more easily oxidized at high temperatures. A layer of molybdenum trioxide has been detected, and it is thought that, since this will evaporate at oxidation temperature, the protective oxide layer can no longer adhere adequately to the substrate.—BNF.

3.6 Electrochemical Effects

3.6.5

The Role of the Cation in the Electrical Double Layer. D. C. GRAHAME. Amherst College. Paper before Electrochem. Soc., Washington Mtg., April 8-12, 1951. ONR Report, Mar. 9, 1951. *J. Electrochem. Soc.*, 98, No. 9, 343-350 (1951) Sept.

Differential capacities of mercury in a number of tenth-normal aqueous solutions of metallic chlorides was measured as a function of potential. Results are interpreted to mean that the solvent sheaths on the positive and negative ions are displaced as the ions approach the interface. New explanations are given for several well-known phenomena connected with the double layer. The surface charge density and integral capacity of the non-diffuse part of the electrical

double layer were calculated from these data. The ratios of the differential capacities were found to approach unity at potentials where the concentration of cations within the double layer is at a minimum. Tables and graphs are included. 13 references.—INCO.

3.6.8

Resistance Polarization. II.—Its Change with Time, and Its Consequent Significance in the Interpretation of Polarization Phenomena in Metal Coating Solution Systems. GEORG FALK, MARTIN KRIEG, AND ERICH LANGE. *Z. Elektrochem.*, 55, No. 5, 396-404 (1951).

As explained in a previous paper [ibid., 54, 132, (1950)] by resistance polarization, $\Delta g\Omega$, is to be understood the ohmic drop of potential occurring in the non-homogeneous phase boundary-layer at electrodes traversed by current, associated with rapid closing and breaking of the electrical circuit. It is differentiated from concentration- and activation-polarizations. Its characteristic features at Pb or Ag/halogen acid and at Pb/H₂SO₄ interfaces were studied. In no case did $\Delta g\Omega$ exceed ~40% of the total polarization and in the halide acid systems the change of $\Delta g\Omega$ with time can be interpreted in terms of a porous structure of the halide coating on the electrode. In the Pb/H₂SO₄ system a gradual material transformation attributable to alternating polarization is clearly recognizable.—MA.

3.6.4, 3.8.2

Contact Potential Differences. IMRE F. PATAI AND MARTIN A. POMERANTZ. *J. Franklin Inst.*, 252, No. 3, 239-260 (1951).

The theory of contact potentials is briefly sketched in terms of the electron theories of metals, consideration being given throughout to metal/metal contacts only. Methods of measuring contact potentials are reviewed historically and critically. The measured values depend upon surface condition, and measurements "in vacuo" are essential if reproducibility is to be obtained. Some of the more reliable values obtained by different methods are compared, and a technique based on the study of current/grid voltage curves in a thermionic valve is advocated. The material of the grid may be altered, and the characteristic curve is measured with the base-metal grid and also when the grid is covered with evaporated sodium. The displacement of the two curves gives a measure of the contact potential between sodium and the metal of the grid. 38 references and a bibliography of 49 important papers are appended.—MA. 4832

3.7 Metallurgical Effects

3.7.2, 6.2.1

Comparison of the Effects of Additions of Titanium, Niobium, and Tantalum on the Properties of Steels. A. KOHN. *Rev. met.*, 48, 687-711 (1951) Sept.

Study of binary and ternary diagrams (iron-niobium, iron-tantalum, iron-titanium, iron-niobium-carbon, iron-tantalum-carbon, iron-titanium-carbon). Influence of nitrogen and effects of the three elements on properties of iron and iron-carbon alloys are given. Sections on structural hardening, influence of quenching and tempering temperatures, and effects of carbon are included. Hardenability,

intercrystalline, corrosion, ageing, temper-brittleness, creep-behavior, hot-workability, and nitriding are discussed. Final section is devoted to consideration of literature on influence of the three elements on the properties of various types of alloy steel such as mild steels with medium chromium contents, 13-18 chromium steels, nickel-free corrosion-resisting chromium-manganese steels, and austenitic nickel-chromium steels. Properties specifically considered are temper-brittleness, oxidation-resistance, creep-resistance, resistance to intergranular corrosion, structural stability, weldability, and low-temperature behavior. Discussion on high-temperature materials for gas turbines is given.—INCO. 4741

3.7.2, 6.4.2

Effect of Alloying Elements on Corrosion Resistance of Casting Alloys. D. C. G. LEES. *Light Metals* (England), 14, No. 162, 494-502 (1951) Sept.

The author gives a brief summary of the available information on the corrosion resistance of aluminum in cast form. His survey includes a consideration of the results of corrosion tests illustrating the effects of different alloying elements, a comparison between aluminum alloys with silicon, magnesium and copper under natural atmospheric conditions, and a consideration of complex alloys. Aluminum-magnesium alloys are most resistant to corrosion, followed by the binary aluminum-silicon alloys. Binary aluminum-copper alloys, whether heat-treated or not, are severely attacked, with the corrosive attack taking the form of pitting.—ALL. 4746

3.7.3, 6.2.5, 6.2.3, 2.3.4, 2.3.7

Investigation of Welds Between Stainless and Low-Carbon Steel. (In Russian). N. Iu. Pal'chuk. *Avtojennoe Delo* (Acetylene Welding), 22, 1-4 (1951) Dec.

Chemical composition, mechanical strength, and corrosion resistance of various combinations of the above were investigated. Data are tabulated and illustrated.—BTR. 4834

3.7.3, 6.4.2, 7.6.1

Light-Metal Welding in Apparatus Construction. (In German). A. MATTING. *Metall*, 5, 429-434 (1951) Oct.

Discusses weldability of the most important aluminum alloys, the problem of weld cracking, corrosion resistance, and the most important welding methods. Includes photographs and macrographs.—BLR. 4841

3.7.3, 8.8.5

Projection Welding of Steel in Heavy Gages and in Dissimilar Thicknesses. E. F. NIPPES AND J. M. GERKEN. *Kesselschl. Polytechn. Inst. Welding J.*, 31, No. 3, 113s-125s (1952) Mar.

AISI 1010 steels were used to investigate the effects of weld current and time, electrode force and projection dimensions on weld formation and quality. Nickel content of the steels is tabulated. Welding 0.187 in. to 0.187 in. steel, 0.250 in. to 0.250 in. steel and 0.040 in. steel to thicker gages are discussed. The effect of projection dimensions on weld quality was not critical. A more uniform weld strength over the recommended current range resulted when the projection was placed in a thicker sheet. Illustrations, discussion, 5 references.—INCO. 4792

November, 1953

3.7.4, 2.3.6

Metallographic Techniques for Austenite Grain Size of Steels in the As-Cast State. EDWARD A. LORIA. *J. Metals*, 3 (1951) Nov.; *Transactions of the American Institute of Mining and Metallurgical Engineers*, 191, 1029-1030 (1951).

In steels exhibiting temper brittleness, it was found that addition of the wetting agent, Zephiran chloride, to a modified picral etch reveals a precipitate not shown by other etching reagents. Best results were obtained by use of 1% Zephiran chloride in 6% nital. Results are illustrated by macrographs.—BLR. 4780

3.7.4, 3.4.6

Influence of Gases in Steels. (In French). A. KOHN. *Metallurgie*, 83, 821-822 (1951) Nov.

The solubility of gases in liquid and solid steel; influence of the liberation of cobalt on the solidification of rimmed ingots; flake formation; hydrogen embrittlement; aging of steel; blue brittleness, and Bessemer steels of low nitrogen content. Charts, tables, macrographs, and diagrams. 83 ref.—MR. 4762

3.8 Miscellaneous Principles

3.8.4, 2.3.9, 3.2.3

Physical and Chemical Adsorption of Long-Chain Compounds on Radioactive Metals. F. P. BOWDEN and A. C. MOORE. *Trans. Faraday Soc.*, 47, No. 8, 900-908 (1951).

Radioactive metal foils were immersed in a long-chain fatty acid, alcohol, or ester for a known time, and then the adsorbed layer was stripped from the surface and examined for radioactivity. The adsorption on platinum and gold is physical but on zinc, cadmium, and copper it may be followed by chemical reaction. Electron-diffraction and lubrication studies confirm these results by showing that the adsorbed film loses its orientation, and lubrication breaks down at the m.p. of the adsorbate in those cases where the adsorption is physical and close to the softening point of the appropriate soap where the adsorption is chemical.—MA.

3.8.4, 3.2.3, 2.3.9

Micrographic Study of the Oxidation of Iron and of the Transformations of Iron Protoxide. (In French) G. CHAUDRON and R. COLLONGUES. *Rev. Met.*, 48, 917-922 (1951) Dec.

Presents results of study of formation of FeO on the surface of the metal, also its decomposition into Fe_3O_4 and Fe. Separate sections deal with laboratory method for preparation of the oxide layer; constitution and mode of formation of the oxide film; and decomposition of the protoxide. Excellent photomicrographs.—BTR.

3.8.4, 3.8.2, 1.6

Comite International de Thermodynamique et de Cinetique Electrochimiques. (International Committee on Electrochemical Thermodynamics and Kinetics.) Proceedings of the 2nd meeting, 1950, 407 pages, 1951. Libreria Editrice Politecnica Cesare Tamburini, Milan, Italy.

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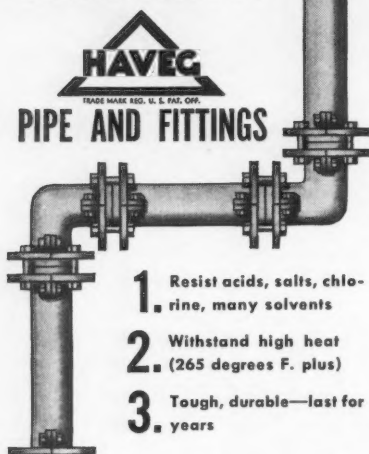
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at above meeting. Divided into the following sections: electrochemical equilibria, electrochemical kinetics, application to the study of corrosion, application to the study of general chemistry and analytical chemistry, polarography, and electrochemical nomenclature and definitions. Selected papers are abstracted separately.—BTR.

3.8.4, 3.4.6

The Parabolic-Linear Oxidation Rate Transition Theory. WILLIAM MCKEWAN AND W. MARTIN FASSELL, JR. Institute for the Study of the Rate Processes, Univ. of Utah, Feb. 1, 1952, 17 p. (AECU-1918; Technical Report No. VII).

A new theoretical concept is proposed to account for the type of oxidation exhibited by metals upon exposure to an oxidizing atmosphere at elevated temperatures. The hypothesis is based on the relative rates of oxidation and recrystallization of the tarnish coating. If the recrystallization rate of the oxide coating formed on the surface is greater than the oxidation rate of the metal, the coating will be protective and hence will follow the parabolic equation. If the reverse situation is true, the coating will be non-protective and the rate curve will be linear. The theory appears to explain qualitatively the experimental results reported in the literature or found by the authors for pure metals. In addition, it provides a new approach to the problem of heat-resistant alloys.—NSA.

3.8.4, 5.9.4

Research on the Revelation and Practical Importance of the Chemical Nature of Electrolytically Polished Metallic Surfaces. P. A. JACQUET AND M. JEAN. *Rev. met.* (France) 48, No. 7, 537-546 (1951) July.

Experiments were carried out on copper, zinc and magnesium polished electrolytically in phosphoric acid, and iron treated in a phosphochrome bath to determine whether an electrolytically polished surface can retain, by adsorption, traces of chemical compounds found in the bath or formed by anodic attack. The following conclusions are given: 1. Employment of colorimetric methods has shown that the surface of copper, zinc and magnesium polished electrically in phosphoric acid can retain a certain quantity of a phosphorus-containing compound. On Armco iron polished in a phospho-chrome electrolyte no trace of phosphorus or chrome was detected. 2. The probability of obtaining surfaces coated with phosphate is greater for copper than zinc (36 and 19 percent respectively). The other surfaces are classed in about the same way, although the values are most frequently divided between the scale 0.025-0.100 and 0.100-0.500 g./cm² for the copper, while they are almost exclusively included in the zone 0.100-0.500 g./cm² for the zinc. About 15 percent of the specimens of the two metals had 0.500 to 2.000 g./cm². 3. About the methods of washing tried, the most effective consisted, in the case of copper, of inserting rapidly in 10 percent phosphoric acid before and after two periods of from 30 to 60 seconds under running water. Immersion of zinc in a solution of 10 percent soda gave equally good results. 4. In the case of copper it appeared that the composition containing the phosphate is fixed by ad-

sorption on the surface and can be removed by sufficient washing. For zinc and especially magnesium a true combination with the metal is possible, and its removal is more difficult. 5. The possible presence of a phosphate impurity on surfaces polished electrolytically in phosphoric acids ought to be taken into consideration when the specimens are being used for research, as even a slight film is sufficient to modify the true properties of the surface. 6. The passive state of iron and steel polished in a phospho-chrome bath is not due to a phosphate or a chromate on the surface, but to a slight but permanent oxide film whose presence explains the characteristics of friction and wear peculiar to those surfaces. This oxide film contributes equally to the improvement in the capacity for cold plastic deformation of certain metals and alloys.—ALL.

3.8.4, 5.9.4, 3.5.9

Mechanism and Kinetics of the Chromizing of Mild Steel in Atmospheres Containing Chromous Chloride. T. P. HOAR AND E. A. G. CROOM. *J. Iron Steel Inst.*, 169, 101-107 (1951) Oct.

Shows experimentally that 0.1% carbon mild steel exposed to atmospheres containing chromous chloride at 950-1100° C. becomes coated with a chromium-rich layer. The over-all rate of chromizing is limited, in the early stages, by the rates of the reactions; and, in the later stages, by the rate of metallic interdiffusion in the growing alloy layer. Various practical chromizing processes are discussed in the light of the experimental results. 17 references.—MR.

3.8.4, 6.2.2, 4.3.2

Dissolution Rate of Iron in 0.1 N Hydrochloric Acid During the First Few Seconds. (In German.) HERIBERT GRUBITSCH AND HIKKA VAYRYNEN. *Werkstoffe u. Korrosion*, 2, 362-365 (1951) Oct.

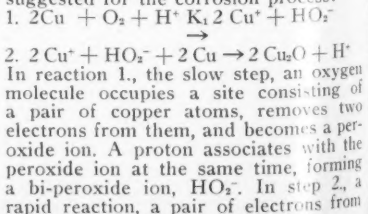
For polished test specimens, the increased dissolution rate in the first few seconds is due to presence of an oxide coating. Tests on specimen free of oxide show an increase in the initial solution rate in both aqueous and ethereal hydrochloric acid. This is explained by increased reactivity of the active iron atoms at the surface. Solubility curve of polished samples is compared with that of coarsely filed samples. 10 references.—MR.

3.8.4, 6.3.6

The Corrosion of Copper in Aqueous Solution. II. GEORGE R. HILL. University of Utah, Technical Report V; Research Contract N7-onr-45103. February 1951. 11 pp., tables, diagrams.

The data obtained from a study of the corrosion reaction of copper are interpreted in terms of rate laws during initial (5-60 sec.), intermediate (2-10 min.), and long-term (10-40 min.) corrosion periods. A mechanism is proposed to account for the initial phase of the corrosion process.

The following reaction sequence is suggested for the corrosion process:



an adjacent pair of copper atoms breaks the oxygen-oxygen bond in the bi-peroxide ion, allowing each O^- to associate with a pair of the Cu^+ ions and releasing the proton to a water molecule in the solution.

The dependence of the initial corrosion process on oxygen concentration was determined by making a series of runs at constant corrosion time (60 sec.) while increasing the partial pressure of oxygen periodically from 42 to 625 mm. between individual runs. From a plot of the reduction plateau time versus the log of oxygen concentration for these runs, the linear slope of the best line was found to be one, indicating first order dependence on oxygen concentration for the slow reaction in the initial corrosion process. The rate constant k_1 for a period less than 60 sec. was 1.90×10^2 liter mol^{-1} sec.⁻¹.

The corrosion rate increased with increasing hydrogen ion concentration between pH 8.3-7.0. The effect indicates somewhat lower than first order dependence on hydrogen ion concentration.

For the corrosion interval from 2-10 min., the reaction follows the parabolic rate law. During this interval the slow step is probably the diffusion of copper ions through the film of corrosion products just formed on the surface. The rate of reaction varies inversely with film thickness. The rate law drops off rapidly to the log time dependence observed in the time interval for 5-60 sec. The rate constant k_2 for 2-10 min. is 2.3×10^8 A² mol^{-1} sec.⁻¹.

For the corrosion interval 10-40 min., the reaction rate is dependent on the logarithm of the corrosion time, suggesting that the slow step in the reaction is a function of a process or surface, the nature of which is itself changing with time.—PDA.

4. CORROSIVE ENVIRONMENTS

4.2 Atmospheric

4.2.3, 6.2.3

The Influence of Carbon Smokes on the Corrosion of Metal Surfaces Exposed to Flue Gases Containing Sulphur Trioxide. R. W. KEAR. *J. Applied Chem.*, 1, pt. 9, 393-399 (1951) Sept.

Results obtained on a mild steel surface confirmed the view that a peak rate in corrosion is obtained at 20-45°C below the dew-point of the gas and that the presence of carbon smokes can profoundly affect the extent of corrosion. As the smoke concentration is increased from zero there is an initial increase in corrosion but eventually the dew-point of the gases and their corrosive properties are substantially reduced. Comparison of the behavior of filtered and unfiltered smoke-laden gases indicate that carbon reduces the sulfur trioxide content of the flue gases by physical adsorption.—INCO. 4734

4.2.7, 5.4.7

Tropical Performance of Fungicidal Coatings. J. M. LEONARD AND A. L. PITMAN. Naval Research Lab. *Ind and Eng. Chem.*, 43, No. 10, 2338-2341 (1951) Oct.

One aspect of the moisture- and fungus-proofing of military electronic equipment is the application of organic coatings. The toxicities of fungi of 100 different toxic agents dispersed in varnish and lacquer vehicles were studied by the exposure of coated cotton-braid wires

in a tropical jungle. The results indicate that most toxicants are inadequate especially at the concentrations now employed. Analysis of the data yields information that will be useful in future experiments. Tables and 11 references are included.—INCO. 4759

4.3 Chemicals, Inorganic

4.3.5, 6.3.6, 6.3.8, 4.4.6

Corrosion of Copper and Lead by Hydrocarbon Solutions of Iodine. (In Russian). L. G. GINDIN AND M. V. PAVLOVA. *J. Applied Chem. (USSR)* (*Zhurnal Prikladnoi Khimii*), 24, 1026-1032 (1951) Oct.

Results of laboratory investigation. Equipment is described and diagrammed; data are tabulated.—BTR.

4.3.6, 6.2.5

Lithium and Its Compounds. R. L. NIELSEN AND M. G. HERRE, Lithium Corp. of America. *Ind. and Eng. Chem.*, 43, No. 12, 2636-2646 (1951) Dec.

During the production of lithium carbonate, the ore passes through a rotary cooler which is an unlined steel cylinder and it is then crushed between a large bull ring of manganese-molybdenum steel and heavy rollers of hard steel. The precipitating tanks are of Type 304 stainless steel. The cooling coils and agitators in the production of lithium hydroxide are of Type 304 stainless steel while the tanks are of steel. Since lithium chloride is extremely corrosive, especially in the presence of water, it is stored in Type 302 stainless steel hoppers and when the

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dryer is shut down, all exposed steel surfaces are washed and steamed to remove the corrosive salt. Steel cathodes are used in the production of metallic lithium. To minimize corrosion problems in handling lithium bromide brine, the salt solution remains in an enclosed, rubber lined system until shipment is made. Graphs, tables and flow sheets for the production of lithium and its various compounds are included. 26 references.—INCO. 4823

4.4 Chemicals, Organic

4.4.2, 6.4.2, 7.5.5

The Effects of Naphthenic Acids on the Corrosion Behavior of Aluminum Alloys in Fuel Tanks. H. PAIGE AND S. J. KETCHAM. U. S. Naval Air Material Center, Philadelphia, Aeronautical Materials Laboratory. April 1951. 23 pp.

A major aspect of corrosion in naval aircraft is the pitting of fuel tanks. Since refineries are now utilizing petroleum fractions of higher boiling point as aircraft fuels, the effects of small quantities of naphthenic acid as an impurity, on some representative naval aircraft metals and alloys required investigation. Weight-loss and coupled-panel corrosion tests were carried out with six aluminum alloys, viz., 7SS-T6, 24S-T3, 2S-H14, 3S-H14, 52S-H14, and 61S-T6, and with J1H magnesium, 60-40 brass, copper, cadmium, 1020 steel, nickel, lead, and tin. The test metals were immersed, at room temperature, in the following synthetic fuels and in water extracts of these fuels: Iso-octane alone and with 30% toluene, iso-octane plus 0.02 or 0.2% naphthenic acid, and iso-octane with 30% toluene plus 0.02 or 0.2% naphthenic acid.

The presence of up to 0.2% naphthenic acids in iso-octane or iso-octane-toluene mixture had no significant effect on any of the metals tested, except lead. Lead showed a large corrosion rate in fuels containing 0.2% naphthenic acids, but was attacked only slightly in these fuels when no more than 0.02% naphthenic acids were present.

In aqueous extracts of the test fuels, 52S-H14 alloy did not suffer significant corrosion when coupled with most of the metals tested. It was consistently pitted, however, when coupled to copper, brass, or lead, and also, though to a lesser extent, when lead or copper ions were present in the water extracts or in distilled water. When coupled to copper, the rate of penetration of 52S-H14 was high enough to puncture a fuel tank within 1 year.

The presence of small, undetermined amounts of naphthenic acids in aqueous fuel extracts tended to suppress the corrosion of all aluminum alloys. This inhibiting tendency was more pronounced for uncoupled specimens; maximum inhibition occurred in water extracts of fuels containing toluene.

From these findings, petroleum fuels containing up to 0.2% acids are recommended as suitable for naval aircraft use provided they are not stored or handled in lead equipment, and provided that, when aluminum alloy tanks are used, adequate precautions are taken to prevent dissimilar metal particles from entering, especially where moisture can accumulate. Plates, tables and diagrams are included.—PDA. 4878

4.4.7, 5.8.2

Characteristics of Oil Additive Agents are Enumerated. A. A. O'KELLY, Alox Corp. Paper before NACE, West N. Y.

Mtg., Buffalo, Nov. 15, 1950. *Corrosion*, 7, No. 2, 8-9, 10 (News Section) (1951) Feb.

General discussion of the use of addition agents in motor oils, rust preventives, corrosion inhibitors and fuel and lubricant additives.—INCO. 4817

4.6 Water and Steam

4.6.1, 1.6

Industrial Water. 1953. 6 x 9 inches, cloth. 336 pp. plus v. Published January, 1953. American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa. Per Copy, \$4.25.

Intended as a reference source for executives and plant designers, persons involved in industrial operations using water, analysts, operators of special instruments, engineers and consultants. The book is the work of ASTM's Committee D-19. Basic information and direction into technical literature are included. It is expected to be helpful to users of ASTM test methods for industrial water and to those planning for water use at supervisory and investment levels. Much information unassembled elsewhere is collected.

The book provides a critical discussion of important problems in the industrial water field and gives all ASTM Standards. Tests for iron bacteria and sulfate reducing bacteria are included.

Chapter IV—Treatment of Industrial Water covers degasification, chemical treatment, corrosion inhibition.

4.6.4, 5.7.1, 7.4.2

Objectives and Techniques of Cooling-Water Treatment. D. MILLER. Permutit Co. Paper before Midwest Power Conf., Chicago. *Oil Gas J.*, 50, No. 16, 139+ (1951) Aug. 23.

Review of current practice in cooling-water treatment both in open and closed systems. Various types of treatment such as addition of zeolite for scale control, de-aeration to remove oxygen, chlorination for control of organic slimes, and polyphosphates and glucosates for prevention of both excessive scaling and corrosion are discussed. The Langelier index and its applications are given. Where heat-transfer surfaces are of corrosion-resistant alloy construction, it is feasible to design treatment for complete elimination of scale-forming constituents. But if ferrous exchange surfaces are used, complete elimination of scale may lead to serious corrosion, particularly in open circulating system where the cooling water is saturated with oxygen due to passage through the cooling tower. 9 references.—INCO. 4922

4.6.6, 5.7.8, 5.8.2

Borax as Corrosion Inhibitor. J. NEWLIN. *Civil Eng.* (London), 22, No. 4, 76 (1952) Apr.

Hydraulics laboratories using a recirculating water system are subject to corrosive action that damages pipes and fittings and causes discoloration of the water, making it difficult to observe flow. At the suggestion of Commercial Solvents Corp., 200 lbs. of borax were added to the 5,000-gallon tank at Rose Polytechnic Institute in 1948. Since then the water has remained clear without further treatment.—INCO. 4796

4.6.1, 3.5.2, 4.3.6

The Formation of Scale from Hard Waters at Temperatures Below the

Boiling Point. A. H. HOWLAND AND W. A. SIMMONDS. *J. Applied Chem.* (London), 1, No. 7, 320-328 (1951) July.

Deposition of calcium carbonate from solutions containing 300-900 p.p.m. of calcium carbonate as $\text{Ca}(\text{HCO}_3)_2$ is negligible below 70° C. Between 75° and 90° the rate of deposition at any time depends upon the degree of super-saturation and the initial degree of supersaturation. Particles of dust, ferric oxide and especially calcium carbonate accelerate deposition.—BNF.

4.6.2, 5.7.9, 3.6.10

Electrical Treatment of Boiler Feed Water. T. F. HURLEY, H. INGLESON, W. J. SPARKES AND R. WILKINSON. *J. Inst. Water Engrs.* (London), 5, No. 7, 686-699 (1951) Nov.

An investigation of the processes which have been described from time to time in which small electric currents are used to induce deposits to form as sludge rather than scale. In tests carried out, marked differences were observed in the quantity and nature of the deposits. These differences do not appear to be associated in any way with the electrical treatment of the feed water, and they are equally apparent whether electrical treatment is used or not. Presumably, they are due to some other variable, the nature of which is not revealed by the tests applied. This variable is elusive and to track it down would probably require a very long investigation.—BNF.

4.6.5, 4.6.2, 8.2.2, 5.7.6, 3.5.7

Boiler Feedwater Treatment for a High-Pressure, High-Makeup, Power and Steam Producing Plant. J. HARLOW (Phila. Elec. Co.), V. J. CALISE, AND M. LANE (Graver Water Conditioning Co.). Paper before Midwest Power Conf., Chicago, April 4-6, 1951. *Proc. Midwest Power Conf.*, 13, 29-303 (1951).

Operation experience with the demineralizer in the treatment of water using anion and cation exchange materials has proved satisfactory. All metal vessels, pumps, piping and valves in contact with acid or demineralized water are either fabricated of Monel or 316 stainless steel or lined with a corrosion-resistant lining. Ion exchange units are lined with sheet rubber vulcanized to the metal surface and most of the piping is lined in the same way. The final effluent water piping to the storage tank and the tank itself are lined with a multi-coat sprayed-on polyvinyl chloride coating. This same coating which has excellent adherent and chemical resistant properties, is used to line the makeup water line which carries the demineralized makeup water from the demineralizing building to the de-aerating heaters at the station. Tables and diagrams are included. 8 references.—INCO.

5. PREVENTIVE MEASURES

5.2 Cathodic Protection

5.2.1, 5.7.1, 5.8.1

Prevention of Corrosion by Means Other Than Protective Coatings. F. L. LAQUE. "Proceedings of the United Nations Scientific Conference on the Conservation and Utilization of Resources. Vol. II. Mineral Resources," 1951, p. 227-234; Disc. p. 240-244.

Control or modification of environments to which metals are exposed. This

may involve reduction in humidity below certain critical limits, addition of specific chemicals which inhibit corrosion reactions, control of air supply, or control of flow of corrosives in contact with the metals. Cathodic protection, proper design, and addition of alloying elements are also discussed. 90 references.—BTR. 4889

52.1, 8.9.3

The Rational Approach to Cathodic Protection. MARSHALL E. PARKER. *Petroleum Eng.*, 23, No. 10, D14, D16, D18 (1951).

It is emphasized that only a detailed study can determine whether cathodic protection will pay in a specific case. A full corrosion survey is essential in all instances. Guidance is given on how to tackle the problem of a pipeline which is already showing leaks, one which has not yet started to leak, and one which is only in the planning stage. Other structures are briefly discussed.—MA. 4830

52.2, 4.5.1

Protection of Metallic Structures From Corrosion in Soil by the Use of Protectors. (In Russian). A. F. LUNEV AND G. V. AKIMOV. *Izvestia Akademii Nauk SSSR, Section of Chemical Sciences*, p. 361-369 (1951) July-Aug.

Experiments were made to evaluate the cathodic protection action of magnesium, a magnesium-zinc-aluminum alloy, an aluminum-zinc alloy, and zinc on iron structures exposed to underground corrosion. Cylindrical castings of magnesium or the magnesium-alloy were found to be superior. Filling the castings with calcium sulfate, calcium sulfate+magnesium sulfate, and similar compounds added to the protective action. Results are discussed, tabulated, and charted.—BTR. 4881

52.2, 8.9.3

Magnesium Anodes for "Hot Spot" Protection. M. E. PARKER. *Oil & Gas J.*, 50, No. 2, 136 (1951) May 17.

Data on the installation of anodes for current drainage when hot spots are located along a bare pipe line. Spacing for anode weights in relation to pipe size and a graph showing current output and anode life as determined by soil resistivity are given.—INCO. 4825

52.2, 8.9.3

Full Protection of Coated Lines with Magnesium. M. E. PARKER. *Oil & Gas J.*, 50, No. 4, 119 (1951) May 31.

Application of complete protection to coated pipe lines. Complete protection is achieved when every point on the line is at a potential of 0.85 volts negative. The advantages and disadvantages of magnesium anodes for cathodic protection and the installation of the system are described.—INCO. 4826

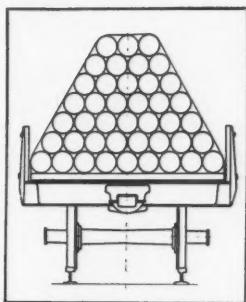
52.2, 8.9.3

Minimum Cost Protection for Secondary Lines. M. E. PARKER. *Oil & Gas J.*, 50, No. 24, 127 (1951) Oct. 18.

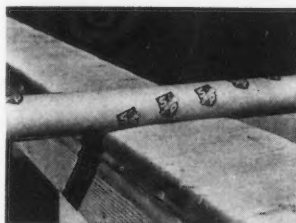
Discussion of secondary piping in the oil industry and elsewhere whose economic status is such that no great expenditure for corrosion control can be justified. Characteristics of secondary piping, and requirements for a low cost program in repairing are given. A simple method of determining the location where protection is needed—the use of magnesium anodes as the least expensive type of protection which can be installed

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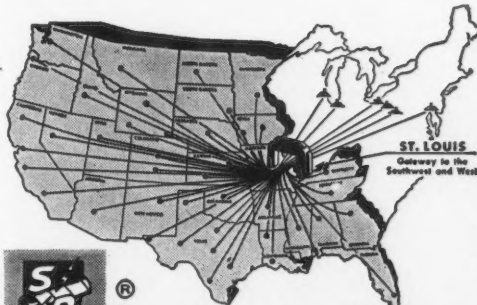
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5.2.3, 8.9.3

Corrosion and Its Control—Ground Beds. M. E. PARKER. *Oil Gas J.*, 50, No. 11, 100 (1951) July 19.

Current drainage of a cathodic-protection unit is through a ground bed. Three factors enter into its design; low current resistance, permanence, and cost. Steel scrap, cast iron, carbon graphite anodes may be used. Details of installation and insulation are given. Copper leads are rubber insulated and then neoprene sheathed.—INCO. 4827

5.2.2, 8.9.3

Performance of Magnesium Anodes Under Actual Service Conditions. T. H.

GILBERT. *Gas Age*, 106, No. 11, 40-41, 67-68 (1951) Nov. 23.

The current outputs of Galvo-Pak Type 1-B or 3-B magnesium anode installations are presented as functions of anode size and soil resistivity. It was found that the total circuit resistance as determined by means of a graph of experimental results agrees, within experimental error, with that deduced mathematically. Using this, the current output can be predicted approximately. Figures 2 and 3 of the paper are graphs of the current output against soil resistivity plotted from actual field measurement. Since these plotted points closely follow the calculated curve and compare favorably with observations made in other parts of the country, it is concluded that the current output during the early life of a

magnesium anode can be predicted with considerable accuracy if the soil resistivity is known. Graphs representing length and size of bare or poorly coated pipe that can be protected by one magnesium anode, versus soil resistivity are included. This enables one to determine the number of anodes required to protect a given length of pipe.—ALL.

5.3 Metallic Coatings

5.3.1, 5.4.1

Protective Coatings of Metals Under Conditions of Atmospheric Corrosion. Papers before Corrosion Group of Soc. of Chem. Ind. & Comm. No. 4—Protection contre la Corrosion—of Assoc. Belge pour l'Etude, l'Essai et l'Emploi des Matériaux, London, Mar. 14, 1952. *Nature*, 169, No. 4302, 603-605 (1952) April 12; *Chemistry and Industry*, No. 16, 353-355 (1952) April 19.

Papers included: 1. "Summary of the Work of the Belgium Commission on Protective Coatings." P. ECUSSISSE. 2. "Report of Tests on the Protective Value of Metallic Coatings Under Sheltered Conditions in Marine Atmospheres." S. G. CLARKE AND W. N. BRADSHAW. 3. "Researches of the Protective Coatings (Corrosion) Sub-Committee of the British Iron and Steel Research Association." F. FANCUTT AND J. C. HUDSON. 4. "Effect of the Impurities in the Metal on the Rate of Corrosion of Zinc and Galvanized Coatings in the Atmosphere." P. T. GILBERT. 5. "Difficulties Encountered in Open-Air Exposure Testing." D. BERMANE. 6. "Comparison of Accelerated Salt Spray Tests on Paints." D. BERMANE. 7. "Mechanism of the Processes Involved in Atmospheric Corrosion Testing." R. ST. J. PRESTON.—INCO. 4875

5.3.2, 2.3.5, 5.9.4

Studies on Zinc-Plated Surfaces by the Measurement of Electrode Potential. II. Effects of Boiling and Heating after Zinc Plating. I. SATO. *J. Electrochem. Soc. (Japan)*, 19, 30-32 (1951); *Chem. Abs. (U. S. A.)*, 45, No. 21, 9399 (1951) Nov. 10th. (Seen in abstract form only.)

The effects of boiling and heating zinc plated surfaces were investigated by measuring the electrode potentials and by a chemical method. Boiling for 15 minutes in a slightly alkaline solution considerably increased the stability of the zinc plated surface. Heat treatment also increased the stability. When the surface had been previously treated by boiling, stability decreased.—ZDA. 4943

5.3.2, 6.4.4

Protection of Magnesium Alloys Against Corrosion by Electrolytic Chromate Films. M. K. PETCH. *Protection and Electrodeposition of Metals. Selected Government Research Reports*, Vol. 3, 216-223, 1951. H. M. S. O. (London).

The conditions were investigated under which chromate films can be formed on magnesium alloy anodes and cathodes in solutions of chromic oxide and of potassium dichromate. The protective efficiencies of the more promising treatments were determined by means of a sea-water spray test. It was concluded that although uniform adherent films may be formed cathodically on magnesium alloys to Specification D.T.D. 118 and anodically on alloys to Specification D.T.D. 120A in a hot 10% solution of potassium dichromate, the properties of the films were not such as to indicate that the process could be used advan-

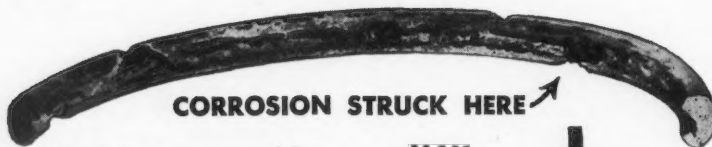
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tageously on a commercial basis. In the former case, the protection obtained was inferior to that given by a simple process already in use, and in the latter case a loss of metal during treatment took place in the same way as it does with the hot $\frac{1}{2}$ -hour bath and the acid chromate dip. Although in this case the protection obtained was better than that produced by the hot $\frac{1}{2}$ -hour bath, the improvement was not considered sufficient to justify recommending a procedure more complicated and difficult than that already in use.—MA. 4850

5.3.2, 6.4.4

Note on the Treatment of Magnesium Alloy to Specification D.T.D. 118 in Cold Chromate Baths (Baths i and ii of Specification D.T.D. 911) After Preliminary Treatment in the Acid Chromate Dip (Bath iv of Specification D.T.D. 911). M. K. PETCH. R. A. E. Technical Note, January 1944, *Government Research Reports* (England), 3, Protection and Electrodeposition of Metals, pages 87-89, H.M.S.O., London 1951.

Tests have shown that the R. A. E. electrolytic and cold chromate treatments applied to material to Specification D.T.D. 118 treated in the acid chromate dip, are not as protective as when applied to bare metal. Pre-existing film should, therefore, be removed before the treatments are applied.—ALL. 4847

5.3.2, 6.4.4, 1.2.5

Selenium Coatings for the Protection of Magnesium Alloys Against Corrosion. L. F. LEBROcq AND H. G. COLE. *Protection and Electrodeposition of Metals*. (Selected *Government Research Rep.* Vol. 3), 1951, 259-266.

Selenium was deposited by a dry method (details of which are not given) and the protection conferred by it compared with that conferred by other methods. The dry method gave as good results on magnesium alloy sheet to Specification D.T.D. 120A and on propeller-blade material as the hot $\frac{1}{2}$ -hour chromate treatment, both with and without subsequent painting. On material to Specification D.T.D. 118 the protection from the dry selenium treatment was inferior to that from the chromate method. Selenium deposited from solution gave good protection to painted D.T.D. 118. Slight extra protection was achieved by depositing selenium on top of the chromate film, but it was not such as to justify the additional operation. The reduction of fatigue strength of the propeller-blade material was no greater when treated by the dry selenium treatment than when treated in the hot $\frac{1}{2}$ -hour chromate bath. It is pointed out that the poisonous nature of selenium and the slight but persistent unpleasant smell of the film do not recommend this treatment.—MA. 4755

5.3.4, 5.3.2, 8.9.4

Metallizes Bridges to Combat Brine Corrosion. *Railway Engineering and Maintenance*, 47, 707-709 (1951), Aug.

Procedure applied to bridge steel by the Missouri Pacific. A life of twenty years is said to be assured. The metal applied is zinc, which is fed in wire form through an oxy-acetylene flame and sprayed onto the steel surfaces.—MR. 4931

5.3.4, 6.2.1

Protection and Decoration of Ferrous Metals. J. LIGER. *Metallurgie*, 82, 403-405,

407, 705-708 (1950); *J. Iron & Steel Inst.*, 168, Pt. 2, 204 (1951).

In the first part, the author surveys protective processes used where the finish is of no account. The advantages and drawbacks of the following are discussed: paints, varnishes, and enamels; galvanizing and tinning; spraying; electrolytic deposition; Sheradizing and Calorizing. In the second part he deals with protection where the final finish is important. Such methods include varnishing, bronzing, light electrolytic protection, nickel and chromium plating, enameling, and painting.—RPI. 4767

5.3.4, 3.7.4

Bright Nickel Plating on Metallic Single Crystals in the Absence of Addition Agents. HENRY LEIDHEISER, JR., AND

ALLAN T. GWATHMEY. *J. Electrochem. Soc.*, 98, No. 6, 225-230 (1951).

Nickel was electrodeposited on electrolytically polished single-crystal spheres of copper and nickel under a wide variety of experimental conditions from a Watts bath which was generally operated in the pH range 3-4. The bath was made up with reagents of different purity, with exactly the same results in each case. The deposit formed on the (100) faces and on faces making a small angle with the (100) plane remained mirror bright to a thickness of 0.01 in. The deposits which formed on the (111) faces and on those faces making a small angle with the (111) plane were matte from the very start of the deposition. X-ray analysis at grazing incidence showed that in the case of the (100) faces the de-

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posit remained monocrystalline, whereas in that of the (111) faces it was polycrystalline. The latter rapidly assumed a (100) preferred orientation under the conditions of the experiment. The hardness of the polycrystalline deposit was found to be greater than that of the monocrystalline one, but its ductility was less. The monocrystalline deposit was compact, but the other was comparatively porous. A few tests were carried out on the relative corrosion-resistance of the two deposits using 10% hydrochloric acid, the action of AC in the Watts bath, and electrolytic etching in nitric acid-acetic acid solution. In all cases the corrosion-resistance of the monocrystalline deposit was the greater. A few preliminary experiments indicated that the high-temperature oxidation properties of monocrystalline nickel, prepared by electrodeposition, were essentially the same as those of a massive single crystal prepared from the molten metal. 3 references.—MA. 4788

5.3.2, 5.3.4

The Coating of Steel With Aluminum. D. P. MOSES AND G. G. POPHAM. *Metalurgia* (England), 45, No. 268. 70-74+ (1952) Feb.

The principal methods for the application of aluminum coatings to steel, in order of importance are: 1) spraying processes, 2) calorizing and heat treatment of sprayed coatings, 3) hot dipping processes, 4) cladding, 5) casting, 6) electroplating, 7) vapor reaction process. The techniques, applications and results to be expected from each of these processes, are discussed. In certain cases these aluminized coatings are preferable to galvanized coatings. For protection in industrial atmospheres for a period of

five years a coating corresponding to a thickness of 3 mils would be needed.—ALL.

5.3.2, 6.4.2

Sprayed Aluminum-Base Coatings for Aluminum Alloys. F. A. CHAMPION. *Metal Industry* (London), 79, 355-358, 384-385 (1951) Oct. 26, Nov. 2.

Laboratory salt-spray tests have shown that sprayed aluminum coatings provide a practical means of raising the corrosion resistance of aluminum-alloy extrusions and castings which contain copper as a major alloying constituent to the high level of clad strong alloy plate and sheet. For aluminum-copper alloys, coatings of 99.5% purity provide adequate protection. Further work is required to develop a technique for spraying satisfactory coatings of higher purity. Application of the principle to other alloys is discussed and the composition of appropriate coatings is suggested.—BTR.

6. MATERIALS OF CONSTRUCTION

6.1 General

6.1.1.3

New Corrosion-Resistant Materials (in Use) Abroad (Outside Germany). VI.-VII. ERICH FRANKE. *Werkstoff u. Korrosion*, 2, Nos. 2, 3, pp. 68-71, 95-101 (1951).

The production, the mechanical and corrosion-resistance properties, and the application of the following materials are described in some detail:

VI. Inconel X containing nickel 70-0, chromium 14-0-16-0, titanium 2-25-2-75, niobium 0-7-1-2, aluminum 0-4-1-0, iron 5-0-9-0, manganese 0-3-1-0, silicon < 0-5,

copper < 0-2, carbon < 0-08, and sulfur < 0-01%. 5 references.

VII. Chromium, nickel, chromium-nickel, chromium-nickel-copper, and chromium-nickel-aluminum steels, 12 references. (cf., *Werkstoff u. Korrosion*, 1, Nos. 4, 5, 8, 9, and 12, pp. 136-143, 171-178, 305-308, 349-357 and 497-506 (1950) April, May, Aug., Sept., Dec.) —MA.

6.1.4.3.5

Sulphur Vs. Construction Materials. *Chem. Eng.*, 58, No. 9, 276-290 (1951) Sept.

Papers in this second Corrosion Forum include: 1. "Sulphur vs. Construction Materials," J. R. West (Mellon Institute). 2. "Worthite," W. E. Pratt (Worthington Pump & Machinery Corp.). 3. "Chlorimets," W. A. Luce (Duriron Co.). 4. "Carbon & Graphite," R. O. Joslyn (National Carbon Co.). 5. "Cements," R. B. Seymour (Atlas Mineral Products Co.). 6. "Coatings," K. Tator (K. Tator Associates). 7. "Durimet 20," W. A. Luce (Duriron Co.). 8. "High Silicon Irons," W. A. Luce (Duriron Co.). 9. "Glass Lining," S. W. McCann (Pfaudler Co.). 10. "Silicones," J. A. McHard and J. T. McIntyre (Dow Chemical Corp.). 11. "Rubber," J. P. McNamee (U. S. Rubber Co.). 12. "Tantalum," L. R. Scriber (Fansreel Metallurgical Corp.).

Topics discussed in No. 1, above, include aluminum, cast iron, silver, silver alloys, lead, cadmium, magnesium, chromium, manganese, copper, copper alloys, nickel, nickel alloys, platinum, stainless steel, ceramics and fused silica.—INCO.

6.1.4.3.7

Materials of Construction vs. Hydrogen Peroxide. *Chem. Eng.*, 58, No. 10, 263-264, 266-268, 270-271 (1951) Oct.

Papers include: 1. "Materials of Construction vs. Hydrogen Peroxide," J. S. Reichert & R. H. Pete (E. I. du Pont). 2. "Nickel & Nickel Alloys," W. Z. Friend (INCO). 3. "High-Silicon Irons," W. A. Luce (Duriron Co.). 4. "Glass Lining," S. W. McCann (Pfaudler Co.). 5. "Worthite," W. E. Pratt (Worthington Pump & Machinery Corp.). 6. "Silicones," J. A. McHard & L. Van Volkinburg (Dow Corning Corp.). 7. "Chlorimets," W. A. Luce (Duriron Co.). 8. "Carbon & Graphite," W. M. Gaylord (National Carbon Co.). 9. "Cements," R. B. Seymour (Atlas Mineral Prods. Co.). 10. "Durimet 20," W. A. Luce (Duriron Co.).

Materials of construction such as aluminum, stainless steel, tin, tantalum, lead, iron, copper, and copper alloys, rubber, plastics, coatings, wood, transit and concrete are discussed in the article by Reichert and Pete in connection with the manufacture, shipping and application of H_2O_2 in the commercial field.—INCO.

6.1.4.4.3

Alcohol vs. Construction Materials. *Chemical Engineering*, 58, 288, 290, 292-294, 296-298, 300-302, 304-305 (1951) Nov.

Introductory portion by William C. Moore is followed by the following brief articles which discuss corrosion resistance of different articles to ethyl alcohol: 1) "Worthite," W. E. Pratt; 2) "Hastelloy," E. D. Weisert; 3) "Glass Lining," S. W. McCann; 4) "Coatings," Kenneth Tator; 5) "High-Silicon Irons," Walter A. Luce; 6) "Durimet 20," Walter A. Luce; 7) "Rubber," O. S. True; 8) "Chlorimets," Walter A. Luce; 9) "Cements," Raymond B. Seymour;

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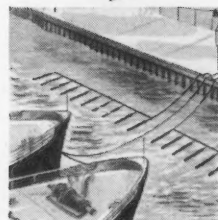
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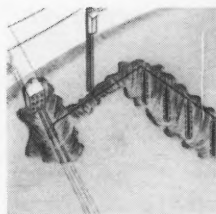
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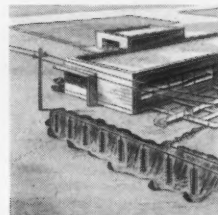
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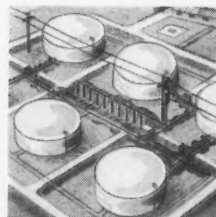
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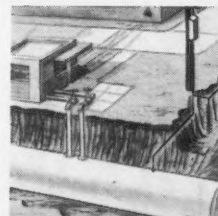
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PIPE-LINE BOOSTER STATIONS



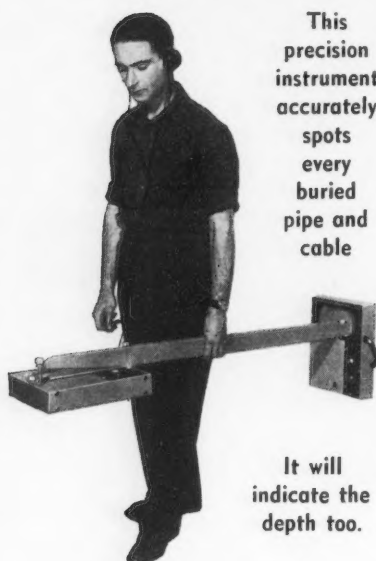
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10) "Iron and Steel," A. W. Spitz; 11) "Nickel and Nickel Alloys," W. Z. Friend; 12) "Stainless Steel," W. G. Renshaw; 13) "Aluminum," J. P. Balash and E. D. Verink, Jr.; 14) "Silicones," J. A. McHard and Leon Van Volkinburg; 15) "Lead," Kempton H. Roll.—BLR.

6.1, 4.4.6

Constructional Materials vs. Hydrocarbon Solvents. *Chem. Eng.*, 58, No. 6 & 7, 220+; 222+; 228, 230 (1951) June, July.

Notes on the corrosion of constructional materials by hydrocarbon solvents; including Durimet 20, aluminum, tantalum, Hastelloy, lead, chlorimets, etc.—MA.

6.2 Ferrous Metals and Alloys

6.2.1, 1.6, 3.7.3

The Making, Shaping and Treating of Steel. J. M. CAMP AND C. B. FRANCIS. 6 x 9, cloth, 1584 pages. Sixth edition, June 1951. The United States Steel Company, Pittsburgh, Pennsylvania. Availability not indicated.

An encyclopedic work on the making and fabrication of steel, the sixth revision of an edition published in 1919. This volume covers in exhaustive fashion the historical and mechanical and economic aspects of steel production, including the necessary ancillary information on equipment and facilities and by-products of the various operations involved.

A 147 page topical index includes 211 references to various aspects of corrosion beginning with "Corrosion, alloying elements for retarding" and continuing through "Corrosion-resistant steels, for seamless tubes." These items include effects of environments, effects of alloying elements, abrasion, types of corrosion, theory, inhibitors, corrosion-resistant finishes, greases, coatings, metal powders, vitreous coatings, foundry practice with corrosion-resistant steel castings, and several kinds of testing.

As a source of general information on steel making and related subjects it is likely this book is among the more comprehensive treatises available.

6.2.2, 3.5.1

Properties and Application of Ductile Iron. G. L. Cox (Inco). *Iron & Steel Engr.*, 28, No. 12, 75-83; Disc. 83-84 (1951) Dec.

Properties of ductile iron, compared with conventional materials, are unique. These properties including ductility, impact, compressive strength, damping, machinability, wear resistance, surface hardening, fatigue, weldability and corrosion resistance are discussed. Graphs, tables, photomicrographs and 12 references are included.—INCO.

6.3 Non-ferrous Metals and Alloys—Heavy

6.3.10, 3.8.2, 3.8.4

Metal-Solution Potentials of Nickel in Foreign-Ion Solutions. D. MACGILLAVRY, J. J. SINGER, JR., AND J. H. ROSENBAUM. *J. Chem. Physics*, 19, No. 9, 1195-1202 (1951).

A potentiometric study of the very

early stages of corrosion led to the consideration if, for a foreign-ion system of a relatively inert metal such as nickel, conditions might exist under which the solution would remain practically free from common ions over more extended periods. After a review of the literature, the metal-solution potentials of nickel in foreign-ion solution is investigated, and it was found that nickel may show stationary potentials in potassium hydroxide and phosphate buffer solution if oxygen is excluded; the stable potentials were reversible with respect to changes in pH. It was noted that nickel was unable to displace hydrogen from 0.1 Molar phosphoric acid solution, and dissolved only on admission of air. 20 references.—MA. 4801

6.3.15, 3.7.3, 8.8.5

Titanium. G. L. MILLER. *Ind. Chemist*, 27, No. 322, 483-491 (1951).

Miller briefly describes the van Arkel process for the production of titanium and gives a more detailed account of the Kroll process. The titanium powders made by these processes are compared. The various methods available for the production of ductile metal from the powder are discussed; these include powder-metal techniques, arc melting, and melting in induction or resistance furnaces. Accounts are given of the methods employed in the working of titanium ingots, and the welding of the metal is described. The mechanical, physical and chemical properties of titanium are reviewed, and its applications are discussed. 9 references.—MA. 4916

6.3.15, 6.3.21

Metals with a Future. I. Titanium. II. Germanium and Gallium. A. D. MERRIMAN. *Practical Engr.*, 23, 24; Nos. 590, 604; 656-657, 375-376 (1951).

I. Titanium—An account is given of the discovery, extraction, and general properties of titanium. II. Germanium and Gallium—The sources, production, and properties of germanium and gallium are discussed.—MA. 4846

6.3.20, 3.2.3, 3.5.9

The Scaling of Zirconium in Air. C. A. PHALNIKAR AND W. M. BALDWIN, JR. *Proc. Am. Soc. Testing Materials*, 51, 1038-1060 (1951).

Both oxygen and nitrogen enter into the above reaction. It forms a double-layered scale: an outer white or buff scale (monoclinic zirconium dioxide) that predominates at temperatures below 1050°C. and an inner black scale (monoclinic and tetragonal zirconium dioxide, cubic ZrN, and possibly N) that occupies the greater thickness at temperatures above 1050°C. The outer white layer does not form immediately but requires a definite time to nucleate. Zirconium strip also undergoes extraordinary dimensional changes during scaling. Increases in dimensions in the rolling plane trebled the original sample area in some cases. Graphs and photomicrographs. 12 ref.—BTR. 4895

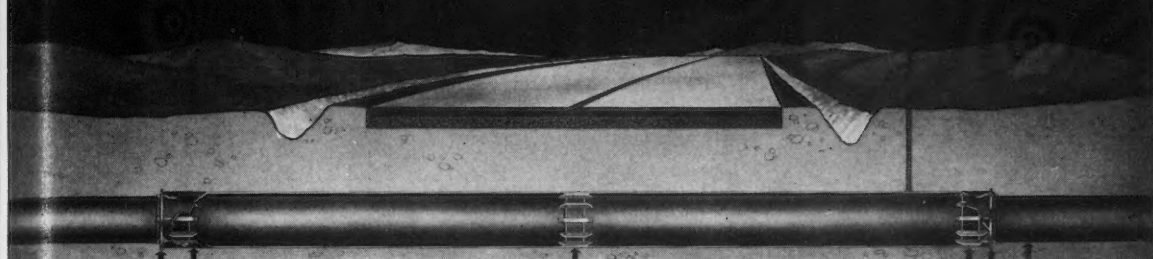
7. EQUIPMENT

7.2 Valves, Pipes and Meters

7.2, 6.2.1, 4.5.1, 5.4.5

Tests on the Corrosion of Buried Iron and Steel Pipes. J. C. HUDSON AND G. P.

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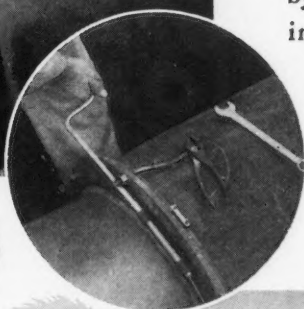


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ACOCK. *Iron & Steel Inst.*, Symposium on Corrosion of Buried Metals, 1951, 1-28 pp. *Foundry Trade J.*, 91, No. 1842, 717-719 (1951) Dec.

This report concerns the corrosion of cast-iron pipes and steel tubes buried in a 5 representative soils in Great Britain for 5 years. The results relate to specimens tested both bare and with various protective coatings. A zinc coating of 2 oz./sq. ft. protected the specimens over the five years, except in made-up ground consisting of ashes, where most of it had corroded away. A 3/4"-thick bitumen coating on steel tube was almost perfect at this site, but a thin hot-dipped coal-tar-pitch coating, 5 mils thick, on cast-iron pipe had failed. Protected specimens were removed from only one other site, in the Keuper Marl, where the bitumen coating was intact but the coal-tar-pitch coating showed signs of failure. Vitreous enamel on cast iron was in perfect condition at this site, but a stoved phenolic resin coating on steel had failed because of its thinness. The tests are being continued.—RPI.

7.3 Pumps, Compressors, Propellers and Impellers

7.3

Indirect Pump Averts Corrosion and Packing Gland Leaks. H. F. REICHARD. *Kellex Corp. Chem. Eng.*, 58, No. 10, 158 (1951) Oct.

Indirect pumping system was the answer to the problem of injection of an extremely corrosive liquid of very low surface tension into a high pressure line. The flow rate of the liquid was

small and closely controlled. The fundamental idea was to enclose the corrosive liquid in a collapsible lead tube contained in a pressure chamber. As a non-corrosive pump oil was forced into the pressure chamber it collapsed the lead tube and forced out into the line exactly an equivalent amount of the corrosive liquid. A sketch of the equipment is included.—INCO. 4930

7.10 Other

7.10

National Physical Laboratory, Teddington—Annual Inspection and Open Days. *Nature*, 167, No. 4260, 1006-1008 (1951) June 23.

The stability under good atmospheric conditions of analytical weights of various materials was studied. For stability of mass, there is little choice between weights of austenitic stainless steel (25 chromium—20 nickel), non-magnetic nickel-chromium (80 nickel—20 chromium), and good rhodium-platinum-, and chromium plated weights having a thickness of 0.015 mm. or more. Chromium-plated weights retained their appearance better than any, except highly polished stainless steel and nickel-chromium, but they are open to objection since the underlying nickel is slightly magnetic. An incidental outcome of the tests is that lead should never be used for the adjustment of screw-knob weights. The tensile properties of copper alloys are very similar if their composition is adjusted to give equal electron-atom ratios. 4794



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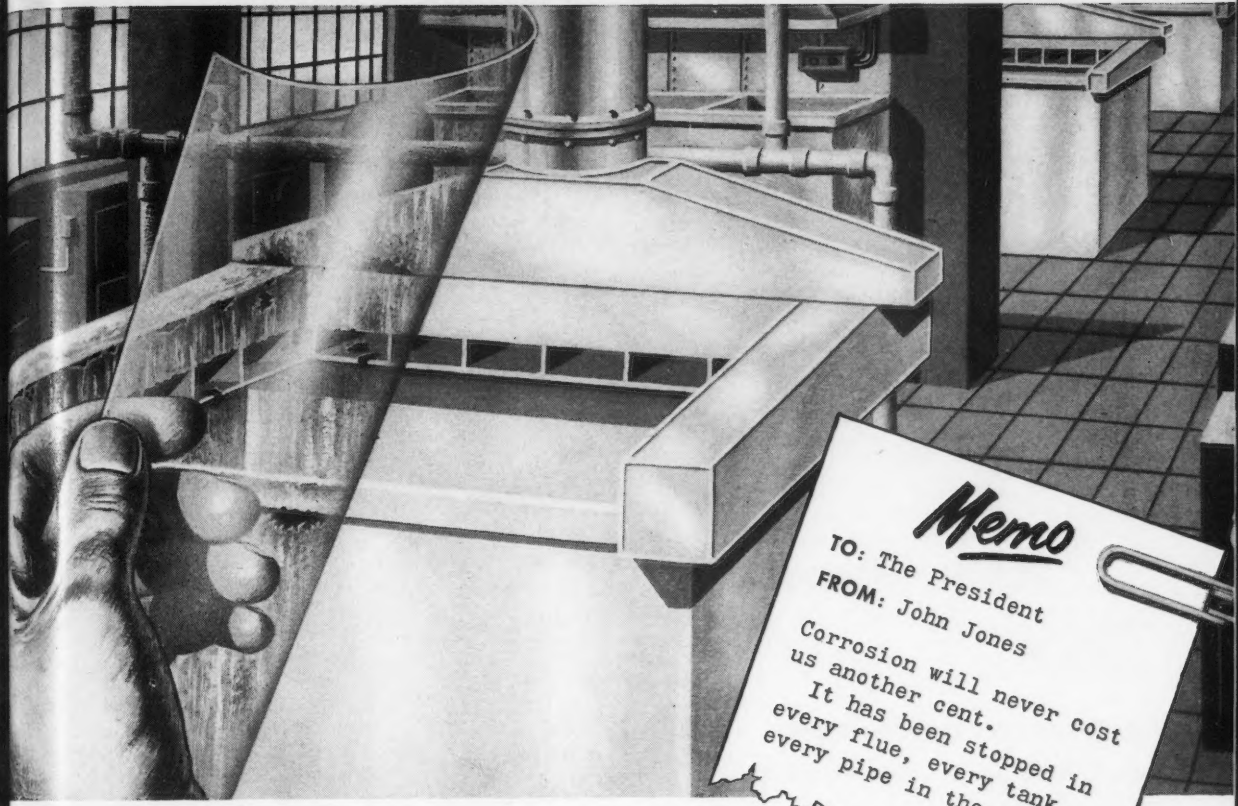
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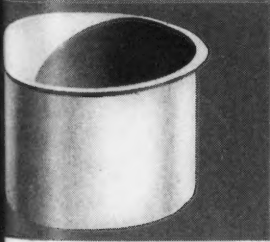


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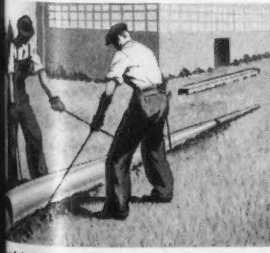
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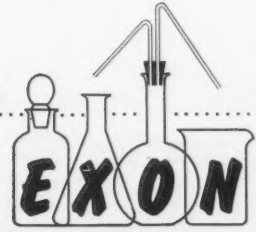
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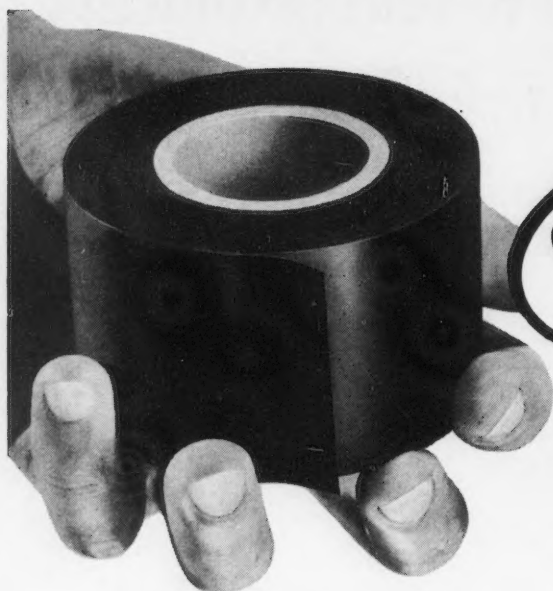
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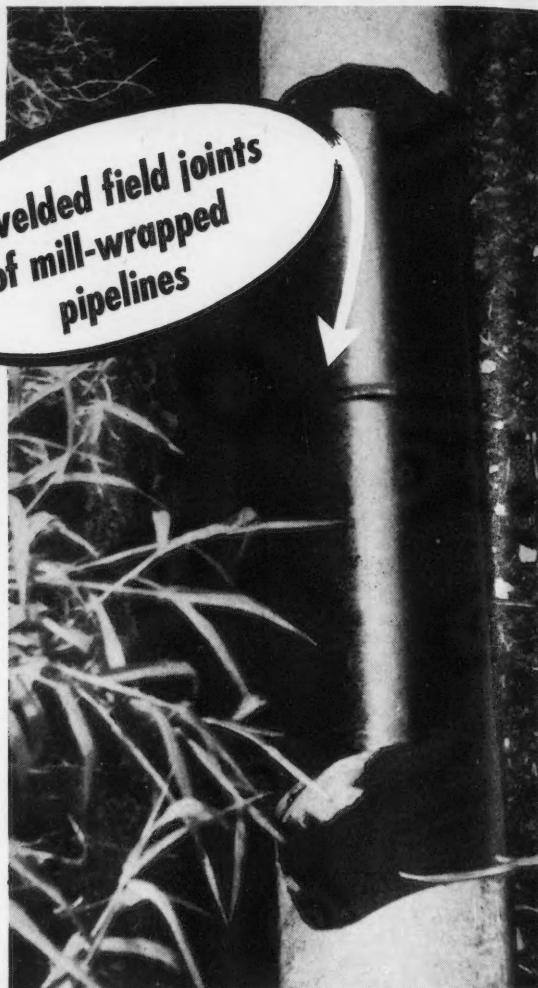
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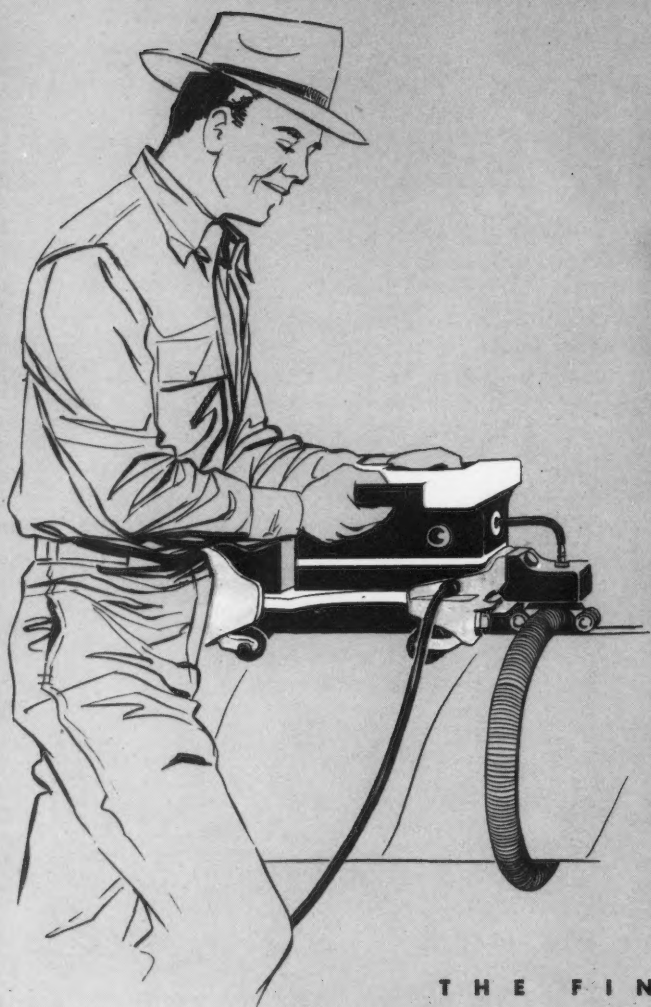
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